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Dr. Pankaj Kumar
Lecturer, Block Institute of Teacher Education (BITE), Madhopatti, Darbhanga, Bihar, India

Corresponding Author:
Dr. Pankaj Kumar
Lecturer, Block Institute of Teacher Education (BITE), Madhopatti, Darbhanga, Bihar, India

Evaluating the effectiveness of the ELPS approach on numeracy conceptualization among middle school students in Bihar

Pankaj Kumar

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Abstract
The increasing demand for effective pedagogical interventions to improve numeracy conceptualization in Indian middle schools necessitates the exploration of innovative teaching frameworks. This research investigates the effectiveness of the Experience, Language, Picture, and Symbol (ELPS) approach in enhancing numeracy understanding among students of classes 6 to 8 in Darbhanga district, Bihar. ELPS, grounded in constructivist learning theory, is designed to help students transition from concrete experiences to abstract mathematical reasoning by integrating multiple cognitive modes. Through a quasi-experimental design involving 180 students across six schools, the study evaluates pre- and post-intervention performance in areas such as number operations, fractions, and algebraic thinking. Statistical tools including paired t-tests and ANOVA were used for analysis. The results reveal significant improvement in numeracy scores among students taught using ELPS compared to the control group following conventional methods. The paper further discusses the implications of integrating ELPS in middle school curricula, challenges in implementation, and recommendations for scaling the model. Visual data representation through tables and plots enhances interpretability. The findings contribute to ongoing policy and pedagogical debates on improving foundational and advanced mathematical competencies in rural India.

Keywords: ELPS approach, numeracy, middle school education, Bihar, conceptual learning, mathematical pedagogy

1. Introductions

Numeracy, the ability to apply mathematical knowledge in everyday life has been recognized as a core component of functional literacy and overall academic success. In the Indian context, however, learning outcomes in mathematics have persistently remained below grade level, particularly in government schools of rural regions like Bihar (ASER, 2022) [8]. While several government-led initiatives such as NIPUN Bharat and foundational literacy programs have attempted to target early grade numeracy, there is a pressing need to extend similar interventions to the middle school stage, where abstract reasoning and algebraic understanding begin to dominate the curriculum.

The Experience, Language, Picture, and Symbol (ELPS) approach, originally introduced in the context of English Language Learners (Echevarria, 1995) [2], has been repurposed in mathematics education as a way to bridge experiential learning with symbolic abstraction. The ELPS framework promotes the development of mathematical concepts by guiding students through real-life experiences (E), discussion and verbal reasoning (L), pictorial representation (P), and formal notation or symbols (S). Its effectiveness lies in addressing diverse learning styles and aiding students in internalizing complex ideas through scaffolded stages of understanding.

Despite growing interest in multimodal and visual learning strategies, little empirical research has been conducted on the use of ELPS in Indian middle school classrooms. This study seeks to fill this gap by evaluating how the ELPS framework affects numeracy conceptualization among students in Classes 6 to 8 in Darbhanga district. The research is rooted in the socio-constructivist paradigm and focuses on assessing academic performance improvements, student engagement, and pedagogical feasibility in low-resource settings

2. Theoretical Background and Literature Review

Numeracy development is not merely about procedural fluency but includes deep conceptual understanding, problem-solving, and the ability to apply mathematical ideas in unfamiliar situations (Kilpatrick, Swafford, & Findell, 2001) [3]. Middle school marks a transitional phase in students' cognitive development where they move from concrete operational to formal operational thinking, as per Piagetian theory. This makes pedagogical models that scaffold abstraction from experience crucial during this phase (Vygotsky, 1978) [6].

The ELPS model integrates elements from Bruner's theory of representational modes, enactive (experience), iconic (picture), and symbolic (symbol), into a coherent instructional strategy. Studies conducted in the United States and Latin America indicate that students taught via ELPS show improved retention and problem-solving abilities in mathematics (Santacruz & Vásquez, 2016) [5]. In India, however, its application remains rare and largely undocumented in government school settings.

Recent Indian studies have emphasized the need for pedagogical models that accommodate the linguistic, cognitive, and socio-cultural realities of learners (Banerjee & Duflo, 2019) [1]. ELPS, with its emphasis on language and context, offers an inclusive learning environment that benefits not only first-generation learners but also students with limited mathematical vocabulary. Additionally, research on visual learning suggests that pictorial representations help students internalize mathematical operations and geometric relations more effectively than purely symbolic instruction (Zhang & Lin, 2015) [7].

Although the ELPS model shows promise in theory, questions remain about its adaptability to multilingual, resource-constrained classrooms in Bihar. This study not only aims to quantify learning gains but also examines qualitative shifts in students' attitudes and teachers' perceptions about the model.

3. Research Methodology

This study employs a quasi-experimental pretest-posttest control group design to assess the effectiveness of the ELPS approach in improving numeracy conceptualization among middle school students. The design allows for the comparison of learning outcomes between a group exposed to the ELPS methodology (experimental group) and another taught through traditional chalk-and-talk methods (control group). Both quantitative and qualitative data were collected to assess not only academic performance but also shifts in conceptual understanding and engagement.

The research was conducted over a period of four months (January to April 2025) in six government middle schools across three educational blocks of Darbhanga district: Bahadurpur, Keoti, and Manigachhi.

A total of 180 students from Classes 6 to 8 were selected using stratified random sampling. The sample was divided into two groups:

- Experimental Group (ELPS): 90 students (45 boys, 45 girls)
- Control Group (Traditional Method): 90 students (44 boys, 46 girls)

The schools were selected to ensure socio-economic diversity, gender balance, and varied academic baselines. The inclusion criteria mandated that all students had basic reading ability in Hindi and had attended mathematics classes regularly during the previous academic session. Teachers for the experimental group received a three-day orientation workshop on ELPS strategies, including lesson planning, visualization techniques, and assessment adaptation.

A standardized Numeracy Conceptualization Test (NCT) was developed in consultation with NCERT and SCERT Bihar guidelines. The test covered key competencies from the middle school curriculum:

- Number Operations (e.g., factors, multiples, decimals)
- Fractions and Ratios
- Geometry (angles, lines, area)
- Pre-Algebra (simple equations, variables)

The test consisted of 30 items (20 objective, 10 short-answer) with a maximum score of 50. Content and construct validity were ensured through expert review and pilot testing in a non-sampled school.

A structured observation schedule was used to monitor the fidelity of ELPS implementation. Focus was given to:

- Use of concrete materials and experiential learning (E)
- Oral interaction and mathematical discourse (L)
- Use of diagrams, charts, and visual aids (P)
- Gradual transition to symbols and equations (S)

Observers rated sessions on a 5-point scale (0 = not observed to 4 = extensively used). And data were analyzed using:

- Descriptive statistics (mean, SD)
- Paired t-test for within-group improvement
- ANOVA for comparing across classes and gender
- Effect size (Cohen's d) to assess magnitude of change

Data were processed using SPSS v26

The ELPS approach was implemented for a total of 24 mathematics lessons (2 per week, 60 minutes each). Each lesson followed a structured format:

- **Experience (E):** Students explored real-world activities (e.g., measuring the classroom with strings to understand perimeter, dividing fruits to demonstrate fractions).
- **Language (L):** Peer discussions, guided questioning, and use of mathematical vocabulary in local language (Maithili/Hindi).
- **Picture (P):** Drawings, use of bar models, number lines, and pattern charts to represent ideas.
- **Symbol (S):** Gradual transition to numeric expressions, formulas, and equations.

Teachers were provided low-cost teaching-learning materials (measuring tapes, cut-outs, chalk diagrams, etc.) to compensate for lack of digital tools.

4. Pre- and Post-Test Results

The table below presents the comparison of mean scores between the experimental and control groups before and after the intervention.

The data indicate a statistically significant improvement in both groups. However, the ELPS group outperformed the control group with a mean gain of 14.44 points compared to 6.29 in the control group, with a large effect size (Cohen's d = 1.21).

Table 1: Pre-test and post-test scores of experimental and control groups

Group	Pre-Test Mean (SD)	Post-Test Mean (SD)	Mean Gain	T-Value	P-Value
ELPS Group (n=90)	21.34 (5.20)	35.78 (6.13)	14.44	15.27	< .001
Control Group (n=90)	20.87 (5.41)	27.16 (5.96)	6.29	6.42	< .001

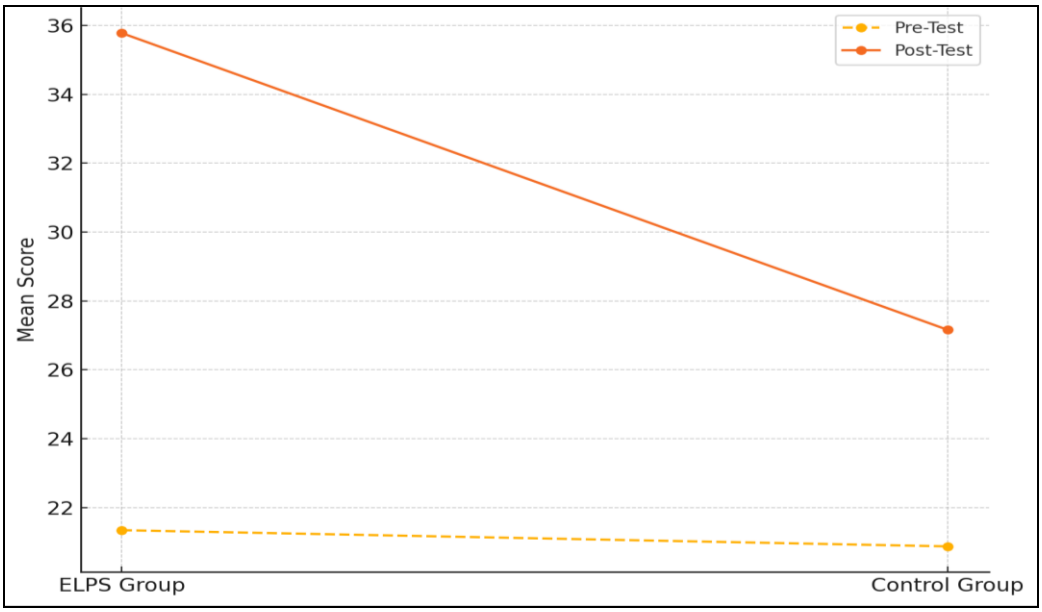

Fig 1: Comparison of mean pre- and post-test scores

This line graph illustrates the steeper learning curve of the ELPS group compared to the control group, validating the effectiveness of the intervention in developing numeracy skills.

To understand how the ELPS approach performed across different subgroups, further analysis was conducted by class (6, 7, 8) and gender. The results showed some variation, particularly in conceptual domains like fractions and pre-algebra.

Table 2: Class-wise post-test performance in ELPS group

Class	N	Mean Score	SD	ANOVA F-Value	P-Value
6	30	34.1	6.02		
7	30	36.4	5.94	3.12	0.049*
8	30	37.9	6.38		

*Significant at $p<.05$

The data indicate a statistically significant difference between classes, with Class 8 students scoring highest, likely due to their greater cognitive maturity and curricular exposure to abstract mathematical ideas. The ELPS approach appeared increasingly effective as students progressed toward higher grades.

An independent samples t-test was conducted to compare learning gains among boys and girls in the ELPS group

Gender	Mean Gain	SD	T-Value	P-Value
Boys	13.9	6.1		
Girls	14.9	6.3	-0.74	0.463

There was no statistically significant difference in learning gains between boys and girls (P=0.463), suggesting that ELPS is an equitable pedagogical tool with uniform benefits across gender.

Observations across all ELPS classrooms revealed consistent implementation of the four stages. However, the intensity and creativity with which teachers conducted each stage varied. The "Picture" stage emerged as the most impactful, with students enthusiastically creating diagrams and models to explain problems.

Table 3: Classroom Observation Ratings (Mean Scores on 5-Point Scale)

ELPS Component	Mean Score	Key Observations
Experience (E)	3.9	Use of string, coins, real objects enhanced engagement
Language (L)	3.6	Encouraged peer discussion; needed more teacher prompting
Picture (P)	4.3	Strong use of diagrams and models; supported retention
Symbol (S)	3.7	Smooth transition in Class 8; struggled slightly in Class 6

Students often related new mathematical ideas to real-life experiences. For instance, in a lesson on ratio, students measured classroom objects and visually compared dimensions using pictorial bars before attempting symbolic equations.

5. Discussion

The results of this study strongly support the integration of the ELPS approach in mathematics instruction at the middle school level in Bihar. The significant improvement in conceptual scores, particularly among older students, affirms the model's alignment with cognitive development patterns and curriculum demands.

Furthermore, the findings align with prior studies indicating that multimodal representation enhances mathematical learning, particularly among students from non-privileged linguistic and educational backgrounds (Zhang & Lin, 2015; Banerjee & Duflo, 2019) [7, 1]. The lack of gender disparity in performance further validates the model's inclusivity.

From a pedagogical lens, ELPS naturally incorporates constructivist principles, where learners actively build knowledge through layered experiences. Unlike traditional rote-based instruction, it allows for deeper schema formation and mathematical discourse, key to numeracy conceptualization (Kilpatrick *et al.*, 2001) [3].

However, some challenges were noted, including inconsistent resource availability, varied teacher enthusiasm, and time constraints in syllabus completion. Nonetheless, these are not barriers to ELPS implementation but rather indicators for systemic support and teacher capacity-building.

As feedback, teachers reported improved student participation and enthusiasm during ELPS lessons. They highlighted the "low-cost adaptability" of the method as a major advantage in government school settings.

"Using matchsticks to explain angles and yarns for measuring length helped even shy students participate", reported one Class 7 teacher from Bahadurpur block.

Students described ELPS sessions as more "fun", "clear", and "different from regular math." Some noted that drawing helped them "understand how numbers behave", particularly in fraction lessons.

6. Policy Implications and Recommendations

The findings of this study highlight the urgent need for curriculum reform that embeds the ELPS approach into mainstream mathematics instruction. The National Council of Educational Research and Training (NCERT) and the Bihar State Council of Educational Research and Training (SCERT) should consider formally integrating ELPS strategies within mathematics textbooks, teacher handbooks, and outcome-based learning frameworks. Lessons that incorporate experiential, pictorial, and symbolic thinking can be added as supplementary modules to enhance conceptual clarity and student engagement, particularly in areas such as fractions, geometry, and pre-algebra.

Another important recommendation relates to teacher training and professional development. To ensure effective implementation of ELPS, District Institutes of Education and Training (DIETs) must embed these methods into both pre-service and in-service teacher education programs. Organizing regular workshops, peer-led demonstration classes, and online resource-sharing platforms can create a community of practice that reinforces consistent use of the ELPS framework across schools in Bihar and beyond. Without strong capacity-building mechanisms, even well-designed pedagogies risk being reduced to superficial routines.

Resource provisioning remains a critical enabler of the ELPS approach, especially in under-resourced government schools. Teaching-learning materials (TLMs) such as paper cutouts, geometry kits, measuring tapes, strings, and visual charts must be made available in classrooms to support the "Experience" and "Picture" components of the model. State education departments can collaborate with local artisans, NGOs, or self-help groups (SHGs) to develop and distribute these low-cost, reusable kits in a sustainable and community-inclusive manner.

Assessment practices also need rethinking. Current examinations often focus on procedural accuracy rather than conceptual depth. In line with the ELPS model, assessments should be redesigned to include pictorial reasoning, oral explanations, and experience-based application questions. Such diagnostic evaluations would offer richer insights into a child's cognitive development and identify conceptual gaps that traditional tests often overlook.

7. Conclusion

This study set out to evaluate the effectiveness of the Experience-Language-Picture-Symbol (ELPS) approach in improving numeracy conceptualization among middle school students in Bihar. Through a rigorous quasi-experimental design, it has been established that the ELPS method significantly enhances mathematical understanding, particularly in areas requiring abstract reasoning, such as fractions and algebra.

The empirical evidence from Darbhanga district supports the theoretical foundation of ELPS, where learning transitions from concrete experiences to abstract symbols. The statistically significant gain in test scores, as well as positive classroom observations and feedback from teachers and students, affirm the model's pedagogical robustness. More importantly, ELPS was shown to be inclusive, gender-neutral, and effective across grade levels, particularly benefiting students who previously struggled with mathematical abstraction.

In low-resource settings like rural Bihar, where teacher quality, student engagement, and conceptual clarity are perennial concerns, the ELPS framework provides a practical, low-cost, and replicable solution. While there are logistical challenges in implementation, such as material availability and time allocation, the approach is adaptable and aligns well with India's educational objectives under the National Education Policy 2020.

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