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ACTHINK RELAY: A GAME-BASED LEARNING INTERVENTION IN ENHANCING STUDENTS' PROFICIENCY IN FRACTION OPERATIONS

A School-Based Action Research

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Abstract

This school-based action research examined changes in learners' performance in fraction operations following ACTHINK RELAY, a non-digital game-based intervention that integrates the Concrete-Pictorial-Abstract approach. The participants were 27 Academic Recovery and Accessible Learning (ARAL) Mathematics learners from Grades 4 to 6 at San Antonio Elementary School in Milagros, Masbate, Philippines, identified through the Department of Education's Rapid Mathematics Assessment. A one-group pretest-posttest pre-experimental design was used. Learners took a 30-item Mathematics Performance Test before and after twelve game sessions delivered over four weeks, and their game experience was described using an adapted Game Experience Questionnaire. The mean score rose from 5.33 to 18.89, and a paired-samples t-test showed a statistically significant difference, with a p-value below 0.001. The share of learners at the Below Basic level fell from 100 percent to 7.41 percent, and learners reported a very high game experience with low negative affect. These findings describe a substantial improvement in the participating learners' scores during the intervention period. However, the one-group design does not establish that the intervention alone caused the change. Teachers may consider the intervention as a supplementary strategy, and further evaluation in additional classes and schools is recommended before broader adoption.

Keywords— *ACTHINK RELAY; fraction operations; game-based learning; Concrete–Pictorial–Abstract approach; ARAL Mathematics; elementary mathematics*

I. INTRODUCTION

A. Background

Fractions are often perceived as inherently abstract, which makes them difficult to teach and learn. Students frequently overgeneralize whole-number rules and struggle to understand fraction magnitude, which hinders later mathematical learning [1]. Addressing these difficulties is therefore crucial to building mathematical fluency and readiness for more advanced topics [2].

Education systems such as those of the United Kingdom, Australia, and Canada have used the Concrete–Pictorial–Abstract (CPA) framework and game-based learning (GBL) to help learners overcome these challenges. The CPA model, associated with the work of Jerome Bruner, moves learners from concrete experiences with physical objects to pictorial representations and then to abstract reasoning [3]. In Australia, the CPA approach has been reported to help students connect concrete experiences with abstract reasoning about fractions [4]. In Japan, it has been described as encouraging collaborative problem solving [5], and in Singapore, combining CPA with GBL has been linked to stronger application of fraction operations [6].

In contrast, the Philippines continues to face serious challenges in mathematics proficiency. In the 2022 Programme for International Student Assessment (PISA), Filipino students averaged 353 points in mathematics, well behind Singapore (575) and Japan (536). Contributing factors include overcrowded classrooms, outdated instructional methods, and limited resources [7]. Difficulties with fractions persist even among preservice teachers, who show deficiencies in working with dissimilar fractions, mixed numbers, and multiplication of fractions [8].

Most studies that combine GBL with CPA come from well-resourced settings, with limited exploration in rural Philippine schools [9], [10]. Non-digital GBL is often preferred by educators in resource-limited environments [11] and offers hands-on learning without advanced technological infrastructure [12]. ACTHINK RELAY (Active Thinking Relay) was designed for this context: a low-cost, team-based relay game that follows the CPA sequence across the four operations on fractions.

B. Statement of the Problem and Hypothesis

This study examined changes in the fraction-operation performance of Grade 4 to 6 Academic Recovery and Accessible Learning (ARAL) Mathematics learners at San Antonio Elementary School, Milagros, Masbate, after the implementation of ACTHINK RELAY. It sought to answer three questions: (1) What were the participants' proficiency levels in fraction operations before and after the intervention? (2) Was there a statistically significant difference between their

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pretest and posttest scores? (3) How did the participants describe their game-based learning experience?

The null hypothesis (H_0) stated that there is no statistically significant mean difference between the participants' pretest and posttest scores in fraction operations. The alternative hypothesis (H_1) stated that there is a statistically significant mean difference.

C. Theoretical Basis

The intervention was informed by Vygotsky's sociocultural perspective, which supports peer interaction and guided participation during collaborative tasks; by Self-Determination Theory, which considers learners' experiences of competence, autonomy, and relatedness [13]; and by the CPA progression from manipulatives to visual representations to symbolic procedures. These perspectives guided the design of ACTHINK RELAY. The study measured fraction-operation performance and reported game experience and did not directly test each theory.

D. Scope and Limitations

The study covered only the selected participants and only fraction operations within the mathematics curriculum. It focused on ACTHINK RELAY and did not control for other factors, such as learners' socioeconomic backgrounds, that may influence learning outcomes.

II. Review of Related Literature

A. CPA in Mathematics

The CPA approach supports fraction learning by pairing concrete and visual representations with symbols. It has been reported to improve students' abilities to compare, add, and subtract fractions and to strengthen their understanding of fractional relationships [14], [15]. Diagrams and graphical displays help learners grasp abstract mathematical ideas [16], and students taught with CPA have shown gains in mathematical thinking and problem solving [17].

B. Game-Based Learning in Mathematics

GBL uses games to achieve defined learning outcomes, promoting engagement and the application of knowledge to real-world situations [18]. It has become a popular teaching method that combines conventional learning with interactive experiences [19], and it has been associated with greater engagement and motivation in mathematics [20]. However, its effectiveness varies with game design, instructional alignment, and learners' prior knowledge, and it may be difficult to implement for students with diverse needs [21].

C. Non-Digital Games

Non-digital games and manipulatives promote collaboration and conceptual understanding. Active recreational mathematics games have been shown to reduce mathematics anxiety and improve performance among primary school children [22], and students have been found to value physical game forms for their concrete experiences and social connection [23]. Comparisons of digital and non-digital approaches indicate that both can benefit learning, with effectiveness depending on implementation quality and student engagement [10].

D. Relay Games and the Present Study

Relay formats have been used to promote participation in mathematics. A polygon relay race improved students' performance and engagement in solving polygon problems [24], and a relay board learning medium increased students' interest and participation [25]. The combination of GBL and CPA has also been examined for teaching fractions [26]. Direct research on relay games that follow the CPA sequence for fraction operations remains scarce, particularly in rural Philippine schools. ACTHINK RELAY addresses this local and methodological gap.

III. Methodology

A. Research Design

The study used a quantitative, pre-experimental, one-group pretest–posttest design. The same participating learners completed a Mathematics Performance Test before and after the intervention. The design allowed the researchers to describe within-group score change but did not include a control or comparison group.

B. Participants and Sampling

The participants were 27 ARAL Mathematics learners from Grades 4, 5, and 6 at San Antonio Elementary School, Milagros West District, Milagros, Masbate. Purposive sampling was used: the learners were identified through the Department of Education (DepEd) Rapid Mathematics Assessment (RMA) as needing additional support in fraction operations, and all 27 completed both the pretest and the posttest. Because participants were purposively selected, with no random assignment and no comparison group, the findings describe this group only and should not be generalized to other learners or schools.

C. Instruments

Mathematics Performance Test. The pretest and posttest was a 30-item test aligned with the DepEd curriculum and covering addition, subtraction, multiplication, and division of fractions. Items were designed to diagnose specific errors. Five mathematics educators rated its content validity on relevance, clarity, simplicity, and ambiguity using a five-point scale adapted from earlier work [27], [28]. Table I gives the interpretation of mean ratings, and Table II summarizes the results: all four criteria were rated highly valid, with an average of 3.75.

TABLE I. Interpretation of Mean Ratings

Range of Means	GEQ Interpretation	Content Validity
4.21–5.00	Very High Experience	Very Highly Valid
3.41–4.20	High Experience	Highly Valid
2.61–3.40	Moderate Experience	Moderately Valid
1.81–2.60	Low Experience	Slightly Valid
1.00–1.80	Very Low Experience	Not Valid

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TABLE II. CONTENT VALIDITY OF THE MATHEMATICS PERFORMANCE TEST

Criterion	Total Score	Mean	Interpretation
Relevance	551	3.67	Highly Valid
Clarity	567	3.78	Highly Valid
Simplicity	559	3.73	Highly Valid
Ambiguity	573	3.82	Highly Valid
Average	**562.5**	**3.75**	**Highly Valid**

Game Experience Questionnaire (GEQ). Learners' experiences were measured with a 28-item questionnaire adapted from the Game Experience Questionnaire [29], which has been used to measure experience in educational game environments [30]. The items cover competence, immersion, challenge, flow, positive affect, negative affect, and engagement, and are rated on a five-point scale from 1 (strongly disagree) to 5 (strongly agree). Mean ratings were interpreted using Table I.

D. The ACTHINK RELAY Intervention

The intervention used concrete, pictorial, and abstract materials in a team relay [31]. Fraction tiles and circles supported concrete work, graph paper and markers supported pictorial work, and whiteboards and worksheets supported abstract work. The class was divided into four groups of six to seven learners, and each group was divided into Concrete, Pictorial, and Abstract subgroups. A facilitator gave each group a fraction problem. The Concrete subgroup solved it with manipulatives and explained the solution to the next member; the Pictorial subgroup represented it with diagrams; and the Abstract subgroup finalized it with numbers and symbols and wrote the complete answer on the board. Members passed the task along by a tap on the shoulder. The first group to relay a complete and correct solution earned a point, and the group with the most points received tokens or certificates at the end. Activities included Fraction Flash Relay, Spin, Solve, and Win, and the ACTHINK RELAY Challenge. The intervention consisted of twelve 30-minute sessions, three per week for four weeks, each ending with a five-item quiz.

E. Data Gathering and Ethics

Parents or guardians received a consent form explaining the purpose and methods of the study. The pretest was administered first, followed by the intervention, and then the posttest and the GEQ. Data were stored digitally without identifiers to protect participants' privacy.

F. Data Analysis

Data were analyzed using RStudio 2024.04. Descriptive statistics (mean and standard deviation) summarized test scores. Proficiency levels were defined as Below Basic (below 50 percent), Basic (50 to 70 percent), and Proficient/Advanced (above 70 percent). Weighted means were used for content validity and GEQ ratings. A Shapiro-Wilk test examined the normality assumption, a paired-samples *t*-test compared pretest and posttest scores at the 0.05 level of significance, and Cohen's *d* described the size of the change, with values of 0.2, 0.5, and 0.8 conventionally read as small, medium, and large.

IV. RESULTS AND DISCUSSION

A. Proficiency Levels Before and After the Intervention

Table III shows the distribution of proficiency levels. Before the intervention, all learners (100 percent) were at the Below Basic level, showing a lack of foundational skills in fraction operations. After the intervention, only 7.41 percent remained Below Basic, 59.26 percent reached the Basic level, and 33.33 percent reached the Proficient/Advanced level. A total of 92.59 percent of learners therefore moved to the Basic level or higher. Learners at the Basic level showed partial understanding and may need further reinforcement, such as problem-solving tasks, real-world applications, and differentiated instruction, to reach advanced mastery.

TABLE III. PROFICIENCY LEVELS IN FRACTION OPERATIONS (N = 27)

Proficiency Level	Pretest (%)	Posttest (%)
Below Basic	100.00	7.41
Basic	0.00	59.26
Proficient/Advanced	0.00	33.33

B. Pretest–Posttest Difference

The Shapiro-Wilk test supported the use of a paired-samples *t*-test. As shown in Table IV, the mean score rose from 5.33 (SD = 2.34) on the pretest to 18.89 (SD = 3.02) on the posttest, a mean gain of 13.56 points. The difference was statistically significant, $t(26) = -18.66$, $p < .001$ (the negative sign reflects pretest minus posttest), with a 95 percent confidence interval for the gain of 12.06 to 15.05. The null hypothesis was therefore rejected.

TABLE IV. PAIRED-SAMPLES T-TEST OF PRETEST AND POSTTEST SCORES

Statistic	Value
Pretest mean (SD)	5.33 (2.34)
Posttest mean (SD)	18.89 (3.02)
Mean gain (posttest minus pretest)	13.56
95% confidence interval of the gain	12.06 to 15.05
$t(26)$	−18.66
p	< .001
Cohen's d (pooled SD = 2.70)	5.02
Paired effect size (d_z)	3.59

Cohen's *d*, computed with the pooled standard deviation of the pretest and posttest scores, was 5.02, and the paired effect size based on the standard deviation of the difference scores was 3.59. Both are very large by conventional criteria. However, because the participants were a small, low-performing group measured twice without a comparison group, these values describe the size of the observed change and should not be read as a precise estimate of the effect of the intervention. The improvement is interpreted as a change associated with ACTHINK RELAY and not as proof that the intervention alone caused it. Other factors, such as regular classroom instruction, repeated exposure to similar items, and maturation, may have contributed.

The result is consistent with studies reporting that GBL can improve engagement, motivation, and learning outcomes in mathematics [20], [19], that non-digital games can improve

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performance and reduce mathematics anxiety [22], and that combining CPA with games supports fraction understanding [14]. It also agrees with reports that relay-based games raise interest and performance [24], [25]. At the same time, the literature cautions that effectiveness depends on game design, instructional alignment, and implementation quality [21], [10], which is why replication in other classes and schools is needed.

C. Learners' Game Experience

Table V presents the GEQ results. Learners reported a very high experience in competence (4.75), positive affect (4.75), challenge (4.74), flow (4.72), immersion (4.70), and engagement (4.69). Negative affect was low (2.25). Together with the high challenge rating, this suggests that learners found the tasks demanding but manageable and did not often experience frustration, anxiety, or confusion. These ratings describe learners' own perceptions of the activity and are consistent with the improvement in scores, but they do not by themselves show that the game caused that improvement.

TABLE V. LEARNERS' GAME EXPERIENCE (N = 27)

Dimension	Weighted Mean	Interpretation
Competence	4.75	Very High Experience
Immersion	4.70	Very High Experience
Challenge	4.74	Very High Experience
Flow	4.72	Very High Experience
Positive Affect	4.75	Very High Experience
Negative Affect	2.25	Low Experience
Engagement	4.69	Very High Experience

V. CONCLUSIONS AND RECOMMENDATIONS

A. Conclusions

The 27 participating learners had significantly higher posttest than pretest scores, and the share of learners at the Below Basic level fell from 100 percent to 7.41 percent. Learners also described ACTHINK RELAY as engaging and enjoyable, with low negative affect. Because the study used a one-group pretest–posttest design without a comparison group, these findings should be read as an observed change associated with the intervention and not as definitive evidence that the intervention alone caused the improvement.

B. Limitations

The sample was small and purposively selected from one school, there was no control group, and the content validity of the test was established through expert ratings. These conditions limit generalization and causal inference.

C. Recommendations

- Mathematics teachers may consider ACTHINK RELAY as a supplementary, curriculum-aligned strategy for fraction operations while continuing to monitor learners' progress through appropriate assessments.
- Learners who reach the Basic level may be supported with problem-solving tasks, real-world applications, and structured collaborative learning to move toward advanced mastery.
- Schools may provide professional development on game-based instruction and low-cost instructional materials to support faithful implementation.
- Future studies should include comparison groups, classroom observers, and delayed posttests to examine causal effects and the retention of skills, and should evaluate the intervention in additional classes and schools before broader adoption.

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AI USE DISCLOSURE

The researchers used ChatGPT by OpenAI to assist with language editing, grammar correction, sentence clarity, consistency checks, and organization of selected sections. AI-generated suggestions were reviewed and edited by the researchers, who checked factual statements and references against the study materials and source documents. AI was not used to generate participant responses, fabricate or alter data, conduct the statistical analyses, or determine the findings. The researchers retain full responsibility for the accuracy, interpretation, originality, and integrity of the manuscript.

REFERENCES

[1] N. Kukulaje, B. A. Bakiweyem, and A. Kombat, "Misconceptions and associated errors made by Basic 7 learners in fractions," *European Journal of Contemporary Education and E-Learning*, vol. 4, no. 1, pp. 45–58, 2024.

[2] A. M. Jarrah, Y. Wardat, and S. Gningue, "Misconception on addition and subtraction of fractions in seventh-grade middle school students," *Eurasia Journal of Mathematics, Science and Technology Education*, vol. 18, no. 10, Art. no. em2167, 2022, doi: 10.29333/ejmste/12070.

[3] R. Trundley and R. Stanford, "The CPA framework: Enhancing conceptual understanding in mathematics," 2018.

[4] L. Hinton and C. Fitzgerald, "Implementing the CPA approach in Australian classrooms: A case study on fractions," *Australian Mathematics Education Journal*, vol. 18, no. 1, pp. 34–48, 2022.

[5] M. Inoue, "Collaborative problem-solving in Japanese mathematics education using the CPA approach," 2018.

[6] Y. H. Cheung and C. K. Tan, "Game-based learning in Singapore primary schools: Promoting engagement and deep learning," *Journal of Educational Research*, vol. 113, no. 3, pp. 230–242, 2020.

[7] A. B. I. Bernardo, "Internalizing mathematical problem-solving strategies: The role of instructional methods in Philippine schools," *Philippine Journal of Education*, vol. 95, no. 1, pp. 25–38, 2019.

[8] A. L. Cantoria Jr., "The predominance of procedural knowledge and between-operation interference as deduced from fraction errors of preservice teachers," *Asia Pacific Journal of Multidisciplinary Research*, vol. 4, no. 3, pp. 75–79, 2016.

[9] T. Hainey, T. M. Connolly, E. A. Boyle, A. Wilson, and A. Razak, "A systematic literature review of game-based learning empirical evidence in primary education," *Computers & Education*, vol. 102, pp. 202–223, 2016, doi: 10.1016/j.compedu.2016.09.001.

[10] M. H. Hussein, "Digital vs. non-digital game-based learning in mathematics: A comparative analysis," *Journal of Educational Technology Systems*, vol. 50, no. 2, pp. 185–201, 2022.

[11] M. Kailani, N. Mohamed, and R. Rahim, "Non-digital game-based learning as a pedagogical tool in mathematics education," 2019.

[12] M. A. B. Setambah, M. Rajoo, M. S. Othman, T. R. Shuib, and M. A. Ibrahim, "Non-digital gamification: Effects of teaching on mathematics achievement and student behavior," *Nurture*, vol. 17, no. 4, 2023, doi: 10.55951/nurture.v17i4.388.

[13] R. M. Ryan and E. L. Deci, "Self-determination theory: A macrotheory of human motivation, development, and health," *Canadian Psychology*, vol. 61, no. 3, pp. 141–150, 2020.

[14] A. C. K. Cheung and S. C. Ng, "Enhancing fraction understanding through the CPA approach: A game-based intervention," *Mathematics Education Journal*, vol. 14, no. 2, pp. 112–128, 2019.

[15] S. B. Empson and L. Levi, *Extending Children's Mathematics: Fractions and Decimals*, 2017.

[16] A. Dreher, S. Kuntze, and S. Lerman, "The role of multiple representations in mathematical learning: Conditions and approaches for teacher support," *Educational Studies in Mathematics*, vol. 91, no. 3, pp. 385–405, 2016.

[17] S. Cai, S. Wang, F. Chiang, and J. Zhang, "Effects of the CPA approach on students' mathematical thinking and problem-solving abilities," *Mathematics Education Research Journal*, vol. 33, no. 3, pp. 456–478, 2021.

[18] H. Hashim, M. M. Yunus, and M. A. Embi, "Game-based learning: Alternative approaches to teaching and learning," *International Journal of Academic Research in Business and Social Sciences*, vol. 9, no. 2, pp. 1–9, 2019.

[19] N. Ahmad and Z. Iksan, "Game-based learning: A review on the effectiveness of educational games," *Journal of Educational Research and Innovation*, vol. 12, no. 3, pp. 45–58, 2021.

[20] A. C. K. Cheung and Y. Luo, "The effects of game-based learning on student engagement in mathematics," *Educational Technology & Society*, vol. 21, no. 3, pp. 1–14, 2018.

[21] L. Ding, J. Xie, and Y. Wang, "Game-based learning in mathematics education: A meta-analysis of effectiveness," *Educational Studies in Mathematics*, vol. 98, no. 4, pp. 435–456, 2018.

[22] H. Alanazi, "The effects of active recreational math games on math anxiety and performance in primary school children: An experimental study," *International Journal of Mathematics Education*, vol. 15, no. 2, pp. 78–92, 2020.

[23] Y. Fang, H. Wang, and H. Sun, "The impact of game-based learning on students' engagement and learning outcomes in mathematics," *International Journal of Technology in Education and Science*, vol. 1, no. 1, pp. 29–36, 2016.

[24] J. Aransado and R. Villano, "Enhancing students' performance in solving problems involving sides and angles of polygon through polygon relay race," *International Journal of Multidisciplinary: Applied Business and Education Research*, vol. 4, no. 2, pp. 224–227, 2023.

[25] R. Rahmatullah, R. Riyadi, and D. Indriati, "The effectiveness of use of the learning media 'relay board' in increasing student's interest in learning mathematics at MTs N Darul Ilmi Banjarbaru," in *Proc. Int. Conf. Mathematics and Mathematics Education (I-CMME 2021)*, 2021, pp. 224–227.

ISSN: **3107-6513**

[26] R. Miller and S. Finkelstein, "Concrete–pictorial–abstract approach in mathematics: Teaching fractions through game-based learning," *Mathematics Education Research Journal*, vol. 34, no. 1, pp. 25–38, 2022.

[27] S. A. Suguitan and R. A. Natividad, "Assessing content validity in educational research: A methodological approach," *Journal of Educational Measurement*, vol. 59, no. 2, pp. 115–132, 2022.

[28] J. Picat, *Validity Assessment in Educational Testing: A Practical Guide*. Academic Press, 2020.

[29] W. IJsselsteijn, Y. de Kort, and K. Poels, *The Game Experience Questionnaire*. Eindhoven, The Netherlands: Eindhoven University of Technology, 2014.

[30] F. De Grove, H. Schoenau-Fog, and A. Bäck, "Measuring the player experience in serious games: The Game Experience Questionnaire," *Computers in Human Behavior*, vol. 106, Art. no. 106235, 2020.

[31] D. H. Clements and J. Sarama, "Learning and teaching with computers: A focus on early mathematics," in *The Cambridge Handbook of the Learning Sciences*, 2nd ed., R. K. Sawyer, Ed. Cambridge, U.K.: Cambridge University Press, 2019, pp. 249–274.