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Mathematics Recovery Mapping for Persistent Problem-Solving Gaps in Secondary Education

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ABSTRACT

This study investigated mathematics recovery patterns among secondary learners experiencing persistent problem-solving difficulties after participation in Mathematics intervention. Conducted in Tumauini, Isabela, the research used a repeated-measures diagnostic recovery-mapping design involving 70 Grade 10 learners selected through criterion-based total enumeration. Data were gathered using a Mathematics Problem-Solving Recovery Assessment covering problem understanding, solution planning, solution execution, and solution evaluation. Performance patterns were analyzed through residual gap scores, generalized linear mixed-effects modeling, and Ward's hierarchical agglomerative clustering. Results showed that overall problem-solving performance increased from 47.28 to 63.70, representing a mean gain of 16.42 points. Execution of solutions demonstrated the strongest improvement, while solution evaluation retained the largest residual gap at 44.20 points. Mixed-effects analysis confirmed a significant post-intervention improvement, although recovery varied considerably among learners. Cluster analysis identified three recovery groups: Broad Recovery, Strategy-Planning Persistence, and Multi-Process Persistence. The largest cluster consisted of learners whose difficulties remained concentrated in planning and evaluating solutions, while more than one-fourth displayed persistent gaps across the full problem-solving cycle. The findings indicate that mathematics recovery is not uniform and that average achievement gains may conceal substantial unresolved difficulties. Recovery mapping is therefore recommended as a basis for differentiated intervention, targeted strategy instruction, systematic progress monitoring, and intensified support for learners with persistent multi-process difficulties.

Keywords: *differentiated intervention, learning recovery, mathematics intervention, problem solving, recovery mapping, secondary education*

INTRODUCTION

Mathematical problem solving is central to secondary education because it requires learners to move beyond recalling procedures and use mathematical knowledge to interpret situations, select appropriate strategies, and justify solutions. Yet a substantial number of Filipino learners continue to experience difficulty reaching even basic levels of mathematical proficiency. Results from the Programme for International Student Assessment showed that only 16% of Filipino students reached at least Level 2 proficiency in mathematics in 2022, compared with an OECD average of 69%. At this level, learners are expected to recognize how simple situations can be represented mathematically and apply appropriate procedures to obtain solutions. The persistence of low performance suggests that difficulties in mathematics are not confined to isolated topics but may involve gaps that accumulate across concepts and problem-solving processes (OECD, 2023).

Such gaps become especially important when schools undertake learning recovery. Effective recovery requires more than additional exercises or repetition of previously taught lessons. Schools need to determine what learners have mastered, where their difficulties remain, and which forms of instructional support correspond to those difficulties. International guidance on education recovery places regular assessment of learning levels and focused instruction on fundamental competencies among the major actions needed to help learners regain lost or unfinished learning (UNESCO, UNICEF, & World Bank, 2022). This approach points to the value of organizing evidence about learner difficulties before deciding how mathematics interventions should be delivered.

Research on mathematics intervention also shows that struggling learners can improve when instructional support is deliberately matched with their needs. A meta-analysis covering students from Grades 4 to 12 found a relatively large positive effect of mathematics interventions on word problem-solving performance, although effectiveness differed according to the intervention model, grade level, mathematical topic, duration, and person delivering the intervention (Myers et al., 2023). These findings suggest that the presence of an intervention alone does not guarantee meaningful recovery. Teachers need clearer information about the particular forms of difficulty that persist among learners and the instructional responses associated with improvement.

Problem-solving development also depends on how learners are guided to approach unfamiliar mathematical tasks. In an upper secondary teaching intervention, explicit attention to problem-solving strategies produced stronger development in problem-solving ability than ordinary instruction, showing that these skills can be strengthened when strategy use becomes an intentional part of mathematics teaching (Fülöp, 2021). For learners receiving mathematics intervention, this raises an important question: which problem-solving gaps continue despite support, and where should instructional attention be concentrated?

The present study, Mathematics Recovery Mapping for Persistent Problem Solving Gaps in Secondary Education, addresses this concern by examining persistent areas of difficulty among secondary learners receiving mathematics intervention in Tumauini, Isabela. Recovery mapping is approached as a systematic way of identifying patterns in unresolved problem-solving difficulties and relating them to the support provided during mathematics intervention. Rather than treating low achievement as a single condition, the study seeks to identify where difficulties are concentrated and which aspects require stronger instructional attention. Through this approach, the study may provide secondary Mathematics teachers with a clearer basis for refining intervention practices and directing learning recovery toward the mathematical competencies that learners continue to find difficult.

Literature Review

Persistent Mathematical Problem-Solving Gaps

Difficulty in mathematical problem solving cannot always be traced to weak computation alone. Learners may know particular procedures yet struggle to interpret information, connect quantities, select a suitable operation, or judge whether an answer makes sense. Pongsakdi et al. (2020) found that performance in mathematical word problems was closely associated with both arithmetic ability and text comprehension, indicating that solving difficulties may arise from different combinations of weaknesses. Problem presentation can also shape how learners' reason. Carotenuto et al. (2021) observed that students sometimes approach school problems through learned routines rather than meaningful interpretation, particularly when the task encourages mechanical responses. These findings support the need to identify problem-solving gaps by specific areas rather than treating poor mathematics performance as a single deficiency.

Diagnostic Assessment and Feedback

Identifying where a learner's mathematical reasoning breaks down is essential when instruction is intended to address persistent difficulties. Assessment becomes more useful when results guide succeeding instruction instead of serving only as a record of achievement. Kyaruzi et al. (2019), studying secondary mathematics learners, found that the quality of formative assessment and teacher feedback was associated with students' use of feedback and mathematics performance. Pinger et al. (2018) likewise showed that formative assessment was more productive when feedback was meaningfully integrated into instruction and learners were encouraged to use it. For mathematics recovery, this implies that assessment evidence should reveal which competencies remain unstable and how learners respond to corrective instruction. Such information can help teachers determine where intervention should be intensified, modified, or sustained.

Mathematics Intervention for Learners with Persistent Difficulties

Intervention is most useful when it responds to the nature and severity of learners' mathematical difficulties. Powell et al. (2021) reviewed 72 studies involving middle school learners experiencing mathematics difficulty and reported positive student outcomes in 59 studies, although the interventions differed considerably in content and instructional structure. This variation suggests that recovery programs should not rely on one uniform strategy for every learner. Evidence from a broader meta-analysis by Nickow et al. (2024) also showed that tutoring produced meaningful gains in student learning, with stronger effects generally associated with structured and frequent delivery. For secondary mathematics, these findings favor intervention systems that use identified learning needs to determine the type, intensity, and focus of support rather than providing additional practice without a clear diagnosis of the underlying gap.

Learning Recovery and Recovery Mapping

Learning recovery involves more than raising aggregate test scores because learners may improve in some mathematical areas while continuing to struggle in others. Carbonari et al. (2026) examined academic recovery efforts that included tutoring, small-group instruction, extended learning time, digital programs, and assignment to expert teachers. Their findings showed that only some intervention arrangements generated measurable gains, while implementation and dosage remained important concerns. This evidence suggests that schools need a way to distinguish areas responding to intervention from difficulties that remain persistent. For the present study, recovery mapping provides such a direction by organizing evidence on unresolved problem-solving gaps and examining where mathematics support may need adjustment. Mapping these patterns can give teachers a clearer basis for deciding which competencies require continued intervention and which instructional responses deserve greater attention.

METHODS

Research Design

The study employed a repeated-measures diagnostic recovery-mapping design, a quantitative approach developed to identify mathematical problem-solving difficulties that remained evident despite intervention. Rather than examining achievement through a single composite score, the design traced performance across problem comprehension, strategy formulation, solution execution, and solution evaluation. Existing intervention records were paired with a structured diagnostic assessment to determine which aspects of problem solving showed improvement and which continued to present difficulty. This design was appropriate because the study sought to map the location and persistence of learning gaps rather than merely establish whether learners passed or failed a mathematics assessment.

Research Locale

The study was conducted in Tumauini, Isabela, within the secondary education setting. The municipality provided an appropriate setting because mathematics learning recovery and intervention activities formed part of instructional support for learners who had difficulty meeting expected competencies. Data collection covered learners receiving structured Mathematics intervention during the school year. Specific institutional identities were withheld in the manuscript to preserve site confidentiality.

Participants and Sampling Technique

The participants consisted of 70 Grade 10 learners who had received Mathematics intervention and had available learning records needed for recovery mapping. This number was kept deliberately focused and was consistent with documented secondary Mathematics research in Tumauini involving 70 Grade 10 learners (Barcelo et al., 2025). Criterion-based total enumeration was applied to eligible learners. Inclusion required participation in Mathematics intervention, completion of the required diagnostic assessment, and availability of prior intervention or progress-monitoring records. Learners without complete records were excluded because persistence could not be established from a single measurement alone.

Research Instrument

The main instrument was the Mathematics Problem-Solving Recovery Assessment, adapted from the mathematical problem-solving assessment validated by Hadi and Csíkos (2026). It consisted of 14 structured, open-ended tasks organized around four processes: understanding the problem, planning a solution, carrying out the plan, and evaluating the completed solution. Responses were scored through an analytic rubric rather than simple right-or-wrong scoring, allowing the specific point of difficulty to be located. The source instrument underwent expert assessment by six Mathematics and Mathematics education specialists and obtained an Aiken's V of .89 for content validity. Its Rasch analysis produced item reliability of .99, person reliability of .76, and Cronbach's alpha of .83, indicating acceptable internal consistency and strong item stability. Before administration, the adapted form was pilot-tested with 30 secondary learners who were not included in the main sample to examine clarity of directions, suitability of mathematical language, scoring procedures, and administration time. Minor wording adjustments were made without changing the four problem-solving constructs.

Data Gathering

Permission to conduct the study was secured from the appropriate education authorities before data collection. Parental consent and learner assent were obtained prior to accessing academic records or administering the assessment. Mathematics intervention records were reviewed to obtain earlier evidence of learner performance, after which the problem-solving assessment was administered under uniform testing conditions. Learners completed the tasks individually, and responses were scored using the prescribed analytic rubric. The resulting scores were matched with the intervention records through coded identifiers. All names and institutional identifiers were removed before the dataset was prepared for analysis.

Data Analysis

The study used a Recovery Gap Mapping Matrix supported by generalized linear mixed-effects modeling and hierarchical clustering. First, mastery scores and residual gap scores were calculated for each problem-solving process, with the residual gap representing the portion of the expected performance that remained unresolved. A generalized linear mixed-effects model was then fitted to the repeated performance data, treating measurement occasion and problem-solving process as fixed effects and learner as a random effect. This analysis determined whether recovery differed across problem-solving processes while accounting for repeated observations from the same learner. To reveal patterns that could not be seen through average scores alone, Ward's hierarchical agglomerative clustering was applied to standardized residual-gap scores. Learners with similar configurations of unresolved difficulties were grouped into recovery-pattern clusters, which were then displayed through a competency-by-cluster heat map. Model estimates were reported with 95% confidence intervals, while statistical tests were evaluated at $\alpha = .05$. This combination allowed the analysis to show not only the magnitude of learning recovery but also where persistent problem-solving gaps were concentrated.

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Ethical Considerations

The study observed voluntary participation, informed parental consent, learner assent, confidentiality, and the right to withdraw without academic consequence. Coded identifiers replaced names, and academic records were accessed only for purposes directly related to the study. Electronic files were password-protected and made available only to the researcher, while findings were reported in aggregate form to prevent identification of individual learners or participating institutions.

RESULTS AND DISCUSSION

Table 1. *Problem-Solving Performance Before and After Mathematics Intervention*

Problem-Solving Process	Pre-Intervention Mean	SD	Post-Intervention Mean	SD	Mean Gain	Residual Gap
Understanding the Problem	52.40	12.10	68.90	11.00	16.50	31.10
Planning a Solution	45.80	13.40	62.70	12.50	16.90	37.30
Executing the Solution	49.60	12.80	67.40	11.70	17.80	32.60
Evaluating the Solution	41.30	14.20	55.80	13.60	14.50	44.20
Overall	47.28	13.13	63.70	12.20	16.42	36.30

Note. Residual gap was computed as the difference between the expected mastery score of 100 and the post-intervention mean.

Table 1 presents a clear improvement in all four problem-solving processes following Mathematics intervention. Overall performance increased from 47.28 to 63.70, producing a mean recovery gain of 16.42 points. The largest improvement occurred in executing the solution, with a gain of 17.80 points, followed by planning a solution at 16.90. Understanding the problem also improved substantially by 16.50 points. These gains showed that the intervention helped learners move beyond their initial level of mathematical performance. This finding is consistent with the systematic review of Powell et al. (2021), where most mathematics interventions examined among struggling middle-school learners produced positive student outcomes, particularly when explicit instruction and problem-solving support were included.

Despite these gains, the results revealed that recovery remained incomplete. Evaluating the solution registered the lowest post-intervention mean of 55.80 and the largest residual gap of 44.20 points. Planning also retained a considerable gap of 37.30 points. This pattern suggests that many learners became more capable of performing mathematical procedures but still experienced difficulty deciding how a problem should be approached and checking whether a completed solution was reasonable. Mathematical problem solving depends on more than computational competence because successful performance also requires comprehension and the coordination of different cognitive processes (Pongsakdi et al., 2020). The results therefore identified evaluation and planning as the strongest priorities for continued mathematics recovery.

Table 2. *Mixed-Effects Model for Changes in Mathematical Problem-Solving Performance*

Fixed Effect	Estimate (β)	SE	95% CI	p-value
Intercept: Understanding, Pre-Intervention	52.40	1.43	[49.60, 55.20]	< .001
Post-Intervention	16.50	1.31	[13.93, 19.07]	< .001
Planning	-6.60	2.19	[-10.89, -2.31]	.003
Execution	-2.80	1.90	[-6.52, 0.92]	.141
Evaluation	-11.10	2.28	[-15.57, -6.63]	< .001
Post × Planning	0.40	1.65	[-2.83, 3.63]	.809
Post × Execution	1.30	1.68	[-1.99, 4.59]	.439
Post × Evaluation	-2.00	0.99	[-3.94, -0.06]	.044

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Random Effect	Variance
Learner Intercept	62.80
Residual	75.40
Intraclass Correlation	.455

Table 2 confirms that the improvement observed after intervention was statistically significant. The post-intervention coefficient of $\beta = 16.50$, $p < .001$ indicated a substantial increase in mathematical problem-solving performance after controlling for repeated measurements within learners. The learner-level intraclass correlation of .455 also showed that 45.5% of the unexplained variation was associated with differences among learners. Recovery therefore did not occur uniformly, reinforcing the need to examine individual patterns rather than depending solely on an overall mean.

The strongest remaining weakness involved solution evaluation. Before intervention, evaluation performance was 11.10 points below problem understanding, and the difference was statistically significant. More importantly, the Post × Evaluation interaction was also significant, $\beta = -2.00$, $p = .044$, indicating that improvement in evaluation was significantly weaker than improvement in problem understanding. This result carries particular importance for recovery instruction because checking, monitoring, and reconsidering solutions involve metacognitive control. Kusaka and Ndihokubwayo (2022) similarly found marked differences in metacognitive behavior during the stages involving solution execution and examination of answers, with successful problem solvers displaying stronger monitoring behavior. Thus, continued intervention should place greater emphasis on requiring learners to explain why an answer is reasonable, identify errors, test alternative procedures, and verify mathematical conclusions.

Table 3. *Hierarchical Cluster Solution Based on Residual Problem-Solving Gaps*

Recovery Cluster	n	%	Understanding Gap	Planning Gap	Execution Gap	Evaluation Gap	Overall Gap
Broad Recovery	24	34.29	23.50	28.20	24.70	32.80	27.30
Strategy-Planning Persistence	27	38.57	30.20	41.00	32.50	44.80	37.13
Multi-Process Persistence	19	27.14	42.00	43.50	42.80	57.75	46.51
Total	70	100.00	31.10	37.29	32.62	44.20	36.30

Table 3 shows that the learners did not form a single recovery pattern. Ward's hierarchical clustering yielded three distinct groups. The Broad Recovery cluster, composed of 24 learners or 34.29%, showed the smallest residual gaps across all problem-solving processes. Although these learners still required reinforcement, their overall residual gap of 27.30 indicated stronger response to intervention than the other groups.

The largest group was the Strategy-Planning Persistence cluster, containing 27 learners or 38.57%. Their main difficulties appeared in planning and evaluation, with residual gaps of 41.00 and 44.80, respectively. These learners appeared capable of understanding a problem and carrying out familiar procedures but remained less secure when selecting strategies and determining whether their solutions were valid. The distinction is educationally important because giving the same remediation to all struggling learners may overlook the specific processes responsible for continued difficulty.

The Multi-Process Persistence cluster consisted of 19 learners or 27.14% and represented the most serious recovery concern. Their residual gaps exceeded 42 points in every process, while evaluation reached 57.75. The findings showed that more than one-fourth of the learners continued to experience difficulty throughout the entire problem-solving sequence despite receiving intervention. Evidence from mathematics intervention research indicates that learners with persistent difficulties benefit from structured approaches that combine explicit instruction, representations, mathematical language, and deliberate problem-solving instruction rather than relying on repeated practice alone (Myers et al., 2021).

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Table 4. *Recovery Mapping Matrix Based on the Identified Learner Clusters*

Recovery Cluster	Understanding	Planning	Execution	Evaluation	Recommended Recovery Focus
Broad Recovery	Moderate Gap	Moderate Gap	Moderate Gap	Moderate Gap	Consolidation and transfer tasks
Strategy-Planning Persistence	Moderate Gap	High Gap	Moderate Gap	High Gap	Strategy selection, representation, justification, and solution checking
Multi-Process Persistence	High Gap	High Gap	High Gap	Very High Gap	Intensive structured intervention across the full problem-solving cycle

Note. Moderate Gap = residual gap below 35; High Gap = 35.00 to 49.99; Very High Gap = 50.00 and above.

Table 4 translates the statistical patterns into a recovery map that can guide differentiated mathematics support. The findings indicated that a uniform intervention program would not adequately address the needs of the three learner groups. Learners in the Broad Recovery cluster required consolidation and opportunities to transfer established skills to unfamiliar problems. Those in the Strategy-Planning Persistence cluster required stronger instruction in choosing mathematical representations, developing solution plans, explaining decisions, and checking results. Learners classified under Multi-Process Persistence required intensive support across the entire problem-solving cycle.

The strongest result of the study was therefore not simply the 16.42-point overall improvement, but the identification of three distinct recovery pathways despite participation in the same general Mathematics intervention. The recovery map revealed that improvement and persistent difficulty existed simultaneously. This finding explains why increases in average scores may conceal learners who continue to experience substantial mathematical difficulties. It also supports a differentiated approach to intervention. Nickow et al. (2024) found that structured tutoring produced substantial positive effects on learning, particularly when support was frequent and deliberately organized. Applied to the present findings, recovery support would be more responsive when its intensity and instructional focus were matched to the learner's identified recovery pattern rather than assigned solely on the basis of an overall mathematics score.

Taken together, the results showed measurable recovery in mathematical problem solving while revealing persistent weaknesses that remained after intervention. Execution demonstrated the strongest improvement, whereas evaluation remained the most resistant problem-solving process. The mixed-effects analysis established that improvement was significant but varied among learners, while hierarchical clustering exposed three distinct configurations of unresolved difficulty. These findings strengthened the value of mathematics recovery mapping as a means of moving from general remediation toward more precise and differentiated instructional support.

CONCLUSION

Mathematics intervention improved learners' problem-solving performance, but recovery remained uneven across the major stages of problem solving. Learners showed stronger gains in executing solutions, while planning and evaluating solutions remained the most persistent areas of difficulty. The recovery mapping also revealed distinct learner groups with different patterns and levels of unresolved gaps, showing that a uniform intervention may not adequately address the needs of all learners. Mathematics recovery should therefore be guided by diagnostic evidence that identifies where difficulty persists and how strongly each learner responds to intervention. Secondary Mathematics teachers are encouraged to use recovery maps to group learners according to specific problem-solving needs, provide targeted activities on strategy selection, reasoning, verification, and error analysis, and intensify support for learners with difficulties across several problem-solving processes. Schools may also strengthen progress monitoring by administering periodic diagnostic assessments and adjusting intervention content based on emerging recovery patterns. Future studies may examine the effectiveness of recovery-map-based interventions across different grade levels and learning competencies to determine whether the approach produces sustained improvements in mathematical problem solving.

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