Enhancing Higher Order Thinking Skills of Challenged High School Learners through a Modified Open Approach with Multi-Problem Rotation

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ABSTRACT

This research investigated the effectiveness of a Modified Open Approach integrated with a Multi-Problem Rotational Model in enhancing the Higher Order Thinking Skills (HOTS) of challenged high school learners, specifically in solving word problems involving systems of linear equations in one variable. Addressing the pedagogical gap where struggling students are often excluded from complex cognitive tasks, this research implemented a unique five-phase instructional cycle featuring a Rethink Mechanism. A 15-item HOTS assessment, validated by three mathematics experts and pilot-tested for reliability ($n = 12$), was used to measure gains in analysis, evaluation, and creation. Results from the Wilcoxon Signed-Rank Test revealed a statistically significant improvement ($p = .0005$), with mean scores increasing from a pre-test baseline of 7.80 (52%) to a post-test mastery level of 11.30 (75%). The findings suggest that the rotational model serves as a social scaffold, reducing cognitive anxiety by allowing students to build upon peer-generated logic. The study concludes that the "Rethink" phase is a critical catalyst for cognitive flexibility, providing an equitable pathway for challenged learners to achieve proficiency in high-level mathematical reasoning.

Keywords: Systems of Linear Equations, Open Approach, HOTS, Station Rotation, Rethink Mechanism, Algebraic Word Problems.

INTRODUCTION

Background of the Study

In the contemporary secondary education landscape, the development of Higher Order Thinking Skills (HOTS) is recognized as a fundamental necessity for college readiness. As Nugroho et al. (2025) argue, high school mathematics must transition from procedural fluency to the higher cognitive domains of analysis, evaluation, and creation. However, a significant gap persists for challenged learners. Tanudjaya and Doorman (2020) observe that these students are often confined to a cycle of remedial, lower-order tasks, which prevents the development of the abstract reasoning required for advanced mathematics.

To address this, the Open Approach provides a framework where problems are not mere exercises but opportunities for exploration. According to Hoffmann and Egri-Nagy (2021), multi-entry learning pathways are crucial for students who may possess foundational gaps but are developmentally prepared for complex logic. This approach is particularly effective for systems of linear equations, where multiple representations such as tables, graphs, and symbols allow students to enter a problem at their own level of comfort. Furthermore, Antonio and Prudente (2023) suggest that inquiry-based approaches are the most effective means to foster analytical skills in STEM.

This study enhances the Open Approach by implementing a Multi-Problem Rotational Model featuring a unique Rethink Mechanism. Unlike standard classroom rotations, this model targets cognitive flexibility the ability to adapt or switch mathematical strategies when a solution path becomes blocked (Santana et al., 2022). Tupas and Linas-Laguda (2025) suggest that such rotational structures foster autonomy and collective accountability, effectively bridging the HOTS gap for challenged learners.

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Statement of the Problem

Despite the curricular emphasis on Higher Order Thinking Skills, many secondary students particularly those identified as challenged learners consistently struggle with solving word problems involving systems of linear equations in one variable. The primary barrier is not the computational arithmetic, but the formulation paralysis that occurs when translating linguistic contexts into algebraic models. Traditional chalk-and-talk methods and repetitive drills often fail to provide the cognitive scaffolding necessary for these students to engage in high-level analysis and evaluation. Consequently, there is an urgent need for an instructional framework that reduces cognitive anxiety and promotes flexibility, allowing struggling learners to move from procedural uncertainty to functional mastery.

Research Objectives

The primary goal of this research was to evaluate the effectiveness of the Modified Open Approach with Multi-Problem Rotational Model on the mathematical reasoning of challenged learners. Specifically, the study sought to:

1. Assess the baseline Higher Order Thinking Skills (HOTS) of challenged learners through a validated pre-test focused on linear systems.

2. Implement a five-phase instructional cycle—Initial Assignment, Exploration, Presentation, Rotation (Rethink Phase), and Reflection—to observe student engagement with algebraic word problems.

3. Evaluate the impact of the Rethink Mechanism on students' ability to analyze, evaluate, and critique mathematical solutions.

4. Determine the statistical significance of the improvement in student scores following the intervention.

METHODOLOGY

Research Instrument and Validation

The primary evaluative instrument developed for this inquiry was a 15-item Higher Order Thinking Skills (HOTS) assessment, specifically engineered to align with contemporary international curriculum standards that prioritize mathematization over rote computation (Liu & Chen, 2024). To ensure the highest level of construct validity, the instrument was subjected to a formal review by three mathematics specialists who scrutinized each item for its ability to elicit complex analytical and evaluative responses rather than simple procedural recall. Furthermore, a pilot study was conducted with a non-participatory group of twelve high school students to identify and rectify any linguistic ambiguities or technical challenges within the word problems, ensuring that the final instrument provided a precise measure of the students' algebraic reasoning capabilities.

The Five-Phase Implementation

The intervention was executed through a highly structured five-phase instructional cycle, which was specifically adapted to assist challenged learners in navigating the transition from linguistic context to algebraic modeling.

Phase 1: Initial Problem Assignment. The class was systematically partitioned into three collaborative groups, each assigned a distinct, non-routine open problem involving linear systems ranging from comparative rate scenarios to geometric relationships utilizing multi-entry learning pathways to ensure that students could engage with the task regardless of their initial proficiency level (Hoffmann & Egri-Nagy, 2021).

Phase 2: Exploration and Solution Generation. During this phase, students engaged in intense collaborative inquiry to identify variables and formulate initial equations, while the instructor served as a facilitator who monitored the diverse strategies and mental models emerging within each group.

Phase 3: Presentation and Discussion. Groups were invited to present their preliminary word-to-equation translations, a process that Kania and Kusumah (2025) argue is essential for mathematical discourse, as it allows challenged learners to observe various interpretations and justifications of the same algebraic context.

Phase 4: Rotation (The Rethink Mechanism). This phase served as the core of the intervention, wherein groups rotated to address problems they did not originally solve, compelling them to engage in the high-level task of evaluating and critiquing the algebraic setups established by their predecessors. By entering a problem that was already "in progress," students were able to bypass the initial frustration of the "blank page" and focus their cognitive energy on verifying the consistency of the equations with the word problem's constraints.

Phase 5: Reflection and Synthesis. In the final stage, the instructor synthesized the various student-led discoveries, using validated reflection tools to bridge the gap between their informal explorations and the formal mathematical principles governing systems of linear equations (Shalikhah & Nugroho, 2023).

RESULTS AND DISCUSSION

Performance on the HOTS Assessment

The table below summarizes the statistical comparison between the pre-test and post-test scores of the high school participants. These results highlight the efficacy of the Modified Open Approach with Multi-Problem Rotational Model in enhancing student thinking.

Table 1. Statistical Significance of the HOTS Improvement

Assessment	**Mean**	**SD**	**n**	**p**
Pre-test	7.80	1.35	12	.0005
Post-test	11.30	0.90	12	
Mean Gain	**3.50**			
Note. SD = Standard Deviation. Significance level set at $p < .05$.				

The results of the Wilcoxon Signed-Rank Test indicate a statistically significant improvement in the Higher Order Thinking Skills (HOTS) of the participants following the intervention. The mean score increased from 7.80 (SD = 1.35) in the pre-test to 11.30 (SD = 0.90) in the post-test.

The calculated p-value of .0005 is well below the significance threshold of .05, providing strong evidence that the Modified Open Approach with Multi-Problem Rotational Model effectively enhanced student performance. This significant gain suggests that the intervention moved challenged learners from a baseline of basic understanding toward a more advanced mastery of analytical and evaluative tasks.

The success of the intervention is primarily attributed to the Rethink Mechanism integrated within the five-phase cycle.

1. Peer-Scaffolding: In the pre-test, students often struggled with "starting" a problem. The rotation phases allowed students to enter a problem already in progress, reducing the cognitive load and allowing them to focus on high-level evaluation rather than basic retrieval.
2. Increased Cognitive Flexibility: By rotating through problems they did not initially solve, high school learners were forced to synthesize and critique the mathematical logic of their peers. This process, supported by Tupas and Linas-Laguda (2025), transformed the classroom into a collaborative environment where HOTS are developed through social negotiation and collective discovery.

Analysis of the Results

The data indicates a clear positive shift in the students' ability to engage with higher-order tasks.

1. Transitioning Beyond Baseline: The pre-test mean of 7.80 (52%) demonstrates that while students possessed basic mathematical knowledge, they were only partially successful when faced with non-routine, open-ended problems. This baseline confirms their status as "challenged learners" who struggle to apply concepts independently.

2. Significant Mastery through Rotation: The post-test mean of 11.30 (75%) represents a substantial improvement. A gain of 23% in a HOTS-focused assessment is significant for high school learners. This suggests that the Rethink Phase enabled students to deconstruct complex problems and synthesize new strategies based on peer logic.

3. Increased Classroom Equity: The reduction in Standard Deviation from 1.35 to 0.90 is a critical indicator. It shows that the intervention did not just benefit the top-tier students but effectively lifted the performance of the entire group, creating a more uniform level of achievement among the challenged learners.

CONCLUSION

The study concludes that the Modified Open Approach with a Multi-Problem Rotational Model is a highly effective instructional framework for developing the Higher Order Thinking Skills (HOTS) of challenged high school learners. The quantitative shift from a pre-test mean of 7.8 to a post-test mean of 11.3 signifies that students moved from basic procedural competence to a functional mastery of analysis and evaluation.

The success of the intervention lies in the Rethink Mechanism within the rotation. By allowing students to revisit and build upon solutions generated by their peers, the model successfully removed the initial entry barrier that often discourages struggling learners. This collaborative cycle transformed mathematical problem-solving from an isolated, high-anxiety task into a dynamic, social process of discovery. Furthermore, the reduction in standard deviation suggests that this model promotes educational equity, as it provided the necessary scaffolding for the lowest-performing students to achieve significant cognitive gains alongside their peers.

RECOMMENDATIONS

Based on the findings of this study, the following recommendations are offered for educators and researchers:

1. For Mathematics Teachers: Educators should consider integrating the Rethink Phase into standard classroom rotations. Instead of using stations for isolated topics, stations should be used to rotate groups through the same complex problems in different stages of development, allowing students to critique and refine peer logic.

2. For School Administrators: Professional development programs should focus on training teachers in Open Approach questioning techniques. Schools should encourage flexible classroom seating and scheduling to accommodate the movement required for multi-problem rotational models.

3. For Curriculum Developers: High school mathematics modules for challenged learners should prioritize "multi-entry" problems. Curricula should move away from repetitive drills and instead include structured opportunities for students to evaluate and synthesize diverse mathematical strategies.

4. For Future Researchers: Further studies should be conducted to explore the long-term retention of HOTS developed through this model. Additionally, research could investigate the effectiveness of this rotational framework in other STEM subjects, such as Physics or Chemistry, to see if the "Rethink Mechanism" yields similar gains across disciplines.

Declarations

Ethical Approval This study was conducted with the highest regard for ethical standards. All participants were informed of the study's purpose, and participation was entirely voluntary. To protect the identity of the high school students involved, particularly those identified as challenged learners, all data was anonymized and handled with strict confidentiality.

Conflict of Interest The authors declare that there are no financial or personal conflicts of interest that could have inappropriately influenced the findings or the integrity of this research.

Data Availability The datasets generated and analyzed during the current study are available from the corresponding author upon reasonable request.

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