

 Research Article

Mayer's Model of Solving Routine and Non-Routine Problems in Linear Word Problems

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Abstract

The Mayer model posits that students learn better from words and pictures than from words alone [HPX1.1], since dual representation of knowledge helps learners to construct verbal and pictorial mental models together and build connections between them. This study adopted Mayer's (1985) model, consisting of problem translation, problem integration, solution planning, and solution execution, to examine problem-solving tasks. The objectives of the study were to translate, integrate, plan, and execute the four phases of linear word problems [HPX2.1]. The methods deployed a convergent parallel design to collect quantitative and qualitative data to compare and interpret the findings. The population was 638 students, comprising 400 and 238 from schools A' and B', and the sample was 350 students, comprising 200 and 150, respectively. And the ages ranged from 15 to 19 years [HPX3.1]. The data were collected through questionnaires and interview guides to complement and enhance validity and reliability. The data was analyzed through descriptive statistics and documents. The respondents had ethical consent, anonymity, permission, and voluntary participation. The key findings showed that the translation phase showed a significant negative statement, but a high presence of undecided responses across both non-routine linear word problems. Integration showed higher performance of students at higher percentiles, even though there were pronounced disparities between routine and non-routine linear problems, with routine problems showcasing higher average scores and less variability compared to non-routine problems. The planning phase showed differences in solving non-routine linear problems in expansion errors, clearing fractions, opening brackets, and grouping like terms. The execution phase consistently showed high percentages of errors in variable definitions and distribution. To minimize errors, we concluded that targeted interventions should strengthen and promote multidisciplinary, transdisciplinary, and interdisciplinary approaches to allow learners to translate, integrate, plan, and execute the four phases of linear word problems.

Keywords: Linear Word Problems, Mayer's Model, Non-Routine

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1. INTRODUCTION

Mathematics is synonymous with problem-solving (Taley & Ndamenu, 2022). Students' ability to solve problems depends on both the teaching model itself and on how they apply it to real-world situations to develop strong everyday problem-solving skills (Fay & Toh, 2023). Specifically, students could accurately arrange, evaluate, and convey data in textual, graphical, and diagrammatic formats. This could enable them to analyze, choose the best course of action, and employ the right methodologies (Taley & Ndamenu, 2022). Kablan and Uğur (2020) and Keleş and Yazgan (2022) stressed non-routine problems in developing students' problem-solving skills.

Word problems provide opportunities for students to acquire the ability to solve problems in contextualized environments without resorting to memorization (Ali, 2023). Real-world problems require mathematical solutions that do not come in the form of equations ready to be solved, but as words that need

to be understood symbolically before being solved algebraically (Baidoo & Ali, 2024). Students are expected to translate word problems, the way they understand them, into equations and apply their mathematical knowledge to solve them. Equations translate our day-to-day word problems into mathematical expressions.

1.1. Linear Word Problems

Moleko and Mosimege (2020) conceive mathematical linear word problems as mathematical puzzles whose main ideas are best expressed as narratives in words. Because they can encourage realistic mathematical modelling and problem-solving (Qetrani et al., 2021), they are a crucial component of the mathematics curriculum. They are sophisticated cognitive tasks that call for several steps and techniques aimed at helping students develop process skills and find solutions to challenging situations (Rizos & Gkrekas, 2024). The ability to solve mathematical problems is an essential skill that students need to develop to enhance their growth and offer intellectual stimulation for promoting mathematical development and understanding.

Verschaffel et al. (2020) intimated that word problems have become students' and teachers' perspectives on the senior high school mathematics word problem-solving activity. Several problem-solving models have been suggested (Emanuel et al., 2021). Voskoglou (2021) suggested Wallas (1926) four-step process, namely Preparation (the solver gathers information about the problem), Incubation (the solver puts aside the problem to do other activities), Illumination (the solver finds the key to the solution), and Verification (the solver checks the solution). Verschaffel et al. (2020) suggested Polya's four-step process, namely understanding the problem (solver restates the problem), devising a plan (solver paraphrases and seeks possible solutions), carrying out the plan (solver deploys all possible solutions), and looking back (solver verifies the solution).

1.2. Routine and Non-Routine Mathematics Problems

Leow and Kaur (2024) contend that mathematics tasks are either routine or non-routine. Routine problems are single-step, easily interpreted problems that take the form of exercises (Calvin, 2023). The student must answer a practical problem using at least one of the four fundamental arithmetic operations. The non-routine plans of action are devised to comprehend the issue, formulate a solution, assess the outcome, and try to resolve the problem. This requires one's unique thinking and inventiveness as puzzles (Krawitz et al., 2021). Non-routine questions give students the chance to practice higher-order thinking skills while they comprehend, analyze, explore, and apply.

Another classification is mechanical and non-mechanical. Mechanical problems involve straightforward manipulation of mathematical symbols and operations without the necessity of contextual understanding (routine problems) (Baidoo & Ali, 2024). Students can rely on procedural knowledge and algorithmic steps to arrive at their solutions (Qetrani et al., 2021).

In contrast, non-mechanical problems require students to interpret a real-world scenario, extract relevant information, and then translate it into a mathematical model (non-routine problems). This process necessitates a higher level of cognitive engagement, including reading comprehension, contextual reasoning, and the ability to identify and apply appropriate mathematical concepts (Ofem et al., 2024). Research (Bukari, 2019) advocates for problem-based learning to gain greater comprehension and engage in real-world problems.

1.2.1. The Problem

The Chief Examiner's Reports of the West African Examinations Council (WAEC) frequently observe students' problems of translating word problems into mathematical phrases (Ali, 2023; WAEC, 2022). Particularly, the reports not only observe the influences of gender, age, and programme differences but also attitudes, anxiety, failure, insecurity, self-confidence, and low perseverance (Aforklenu & Bukari, 2023; Wakhata et al., 2024).

Also, linear equation word problems are crucial in algebra, as they involve translating a word problem into a mathematical expression or equation of the first order. The solutions require both problem representation and problem execution (Capone et al., 2021; Rembert et al., 2019; Santos-Trigo, 2024). However, students are incapable of representing statements in mathematical linear word problems (Taley, 2022). Worst still, students are inept in utilizing a variety of problem-solving strategies that are more innovative and efficient, in the form of diagrams, patterns, and special values or situations to aid in the development of mathematical problem-solving skills (Rizos & Gkrekas, 2024).

Again, cultural and socioeconomic factors play a role in shaping students’ attitudes toward word problems (Rembert et al., 2019). Students from different cultural backgrounds may have varying levels of exposure to certain types of problems and instructional methods, which can influence their comfort and familiarity with word problems. Socioeconomic factors can affect access to resources and support systems that facilitate learning, impact attitudes and performance (Wakhata et al., 2024).

1.3. Theoretical Framework

Thorndike’s theory of stimulus-response is driven by motives to help one achieve the goal, and ineffective stimuli progressively disappear, and can be explained by readiness, effect, and exercise (Ni & Lu, 2020). The law of readiness requires that teachers endeavour to constantly expose students to practice word problems. Teachers should ensure that students drill, rehearse, and assimilate concepts until they are fully meaningful.

The law of effect requires that teachers train students to appreciate word problem learning in their everyday learning experiences, satisfaction, and rewards (Taley, 2022). It behooves teachers to provide word problems that are meaningful and related to real-life situations (Saadati & Celis, 2023). The law of exercise requires that students solve more word problems to learn to use word problems and apply them to a variety of contexts (Ni & Lu, 2020).

1.3.1. Conceptual Framework

The researchers adopted Mayer’s (1985) four-step problem-solving strategies, namely problem translation, problem integration, solution planning, and solution execution.

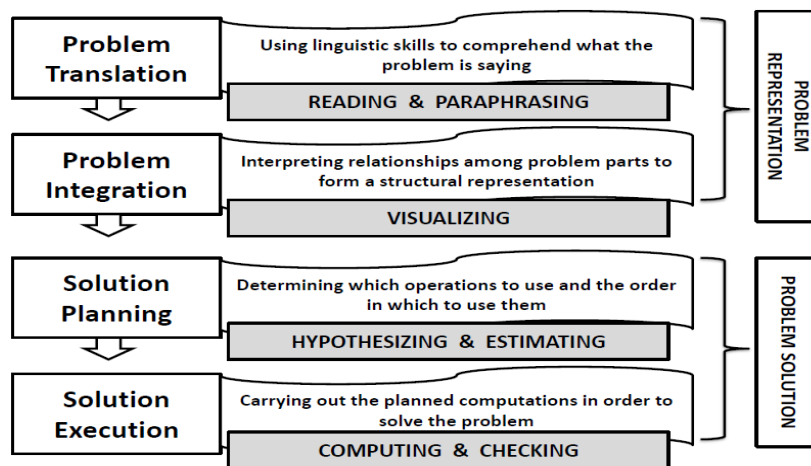


Figure 1. Mayer’s Model of Problem-Solving (adopted from Madzorera & Essien, 2018)

In Figure 1, problem translation is on the linguistic skills required to comprehend the demands of the problem (Madzorera & Essien, 2018). When a student reads the problem for the first time and builds an internal representation of each proposition in the text, then they are often in the translation phase (Taley, 2022). At this stage, students read the problem to ensure they understand it, and then they paraphrase the problem using their own words (Madzorera & Essien, 2018; Moleko & Mosimege, 2020).

Problem integration refers to a student’s ability to comprehend the relationships between the various components of an issue and create a structural representation (Madzorera & Essien, 2018). Students

visualize the problem by creating a schematic representation; the problem integration step is essentially where schematic expertise is most needed. Solution planning is more about showcasing a certain kind of significant picture or diagram to enable students to carry out the scheduled computations to solve the problem and then verify them (Madzorera & Essien, 2018; Powell et al., 2020).

1.4. Research Questions

This study was guided by the following research questions:

1. What non-routine linear word problems do students translate?
2. How do students integrate non-routine linear word problems?
3. What errors emerge in the planning for non-routine linear word problems?
4. How do students counter errors in the execution phase of linear word problems?

2. METHODOLOGY

2.1. Research Approach

The philosophical approach of pragmatism is especially well-suited to mixed research methods (Kaushik & Walsh, 2019). The researchers employed a mixed-methods approach. The mixed method study involves gathering and evaluating both quantitative and qualitative data for the research project. This method leverages the potential benefits of both qualitative and quantitative techniques, enabling us to investigate many viewpoints and reveal connections among the complex levels of our multidimensional question sets. Research using a mixed methods approach necessitates a deliberate blending of data collection, data processing, and evidence interpretation techniques. The overall goal of mixed methods research, combining qualitative and quantitative research components, is to enhance and support a study's findings and thereby add to the body of published literature.

2.2. Research Design

The research design process adopted the flow in Figure 2.

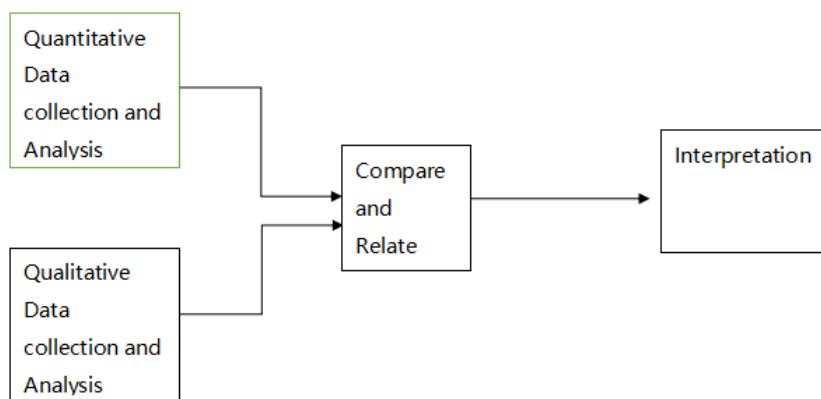


Figure 2. The Convergent Mixed-Parallel Design (Gavaz et al., 2021)

In Figure 2, the convergent parallel design consisted of both quantitative and qualitative data collection and analysis, comparing or relating the two, and interpreting them. In this design, quantitative and qualitative data were collected simultaneously but analyzed separately, and the results were merged or integrated (Gavaz et al., 2021). The focus on integration offered a more thorough comprehension of a research problem. This was intended to triangulate the results from types of data. For instance, by allowing for triangulation, the comparison or integration of findings improved the overall results' validity and reliability and strengthened the robustness, consistency, or convergence of the qualitative and quantitative findings (Demir & Pismek, 2018).

Furthermore, the qualitative aspects enabled the interpretation of objects in their natural settings to make sense of important viewpoints and explanations of students' problem-solving abilities. The quantitative aspects enabled the researchers to make inferences from numeric data. This balances the quantitative and qualitative components at the same stage and interprets the results collaboratively (Demir & Pismek, 2018).

2.3. Population, Sample, and Sampling Techniques

Table 1 describes Form 2 students in Senior High School from two schools that made up the study's accessible population. There were about 638 students. This comprised 400 and 238 from schools 'A' and 'B' respectively. The sample was 350 students, comprising 200 and 150 from Schools 'A' and 'B' respectively. This sample size was determined by Yamane's formula. A sample of all of the units selected for the sample from the population must include all types of population features (Singh, 2022). Therefore, the researchers ensured that they encompassed gender, age, programme of study, and attitude toward problem-solving in the different population units.

Table 1. Distribution of Population and Samples Based on Students

School	Population	Sample
School 'A'	400	200
School 'B'	238	150
Total	638	350

The basic random sampling method was used to ensure every student had an equal opportunity to be chosen for the quantitative phase, unaffected by the selection of other units from the population. This method involved drawing students' names from a box, with random numbers generated starting from a predefined 'seeded' number at the beginning of the programme. The maximum variation purposive sampling was used to select respondents who cut across all content, contexts, and applications of linear problem-solving. This ensured the data included all responses (Singh, 2022).

2.4. Research Instruments

The primary instruments utilized included closed-ended and open-ended questionnaires, interviews, and classroom observations. Employing these diverse methods of data collection complemented each other and enhanced the validity and reliability of the data. The questionnaire was structured to gather data on the attitude inventory. The attitude inventory consisted of eight items on a five-point Likert scale questionnaire, rating their agreement or disagreement with the statements. The scale ranged from Strongly Agree (5) to Strongly Disagree (1), with four items assessing positive attitudes (2, 3, 5, 8) and four assessing negative attitudes (1, 4, 6, 7). Scores exceeding 3 indicated a positive attitude, while scores below 3 indicated a negative, with scores closer to 4 indicating greater positivity and those closer to 2 indicating more negativity. Negative statements were interpreted by reversing responses to positive ones to ensure uniform comparison. The total scores of every attitude category reflected the degree of positive attitude within that category.

The first part of Section B comprised ten (10) test items covering both linear equation routine and non-routine word problems. These items aimed to assess students' proficiency in solving routine and non-routine problems. The first category (items 1–5) focused on routine problems, while the second category (items 6–10) presented non-routine word problems. Each question in the routine category corresponded to an equivalent question in the non-routine category (e.g., Q1 ↔ Q6, Q2 ↔ Q7, etc.). Students were expected to apply basic mathematical concepts to solve these problems, with the non-routine problems requiring more critical thinking and problem-solving (Kablan & Uğur, 2020).

The second part of Section B focused on the qualitative data. Students were engaged to utilize heuristic strategies to approach these problems, facilitating their understanding and progression towards a solution. The five linear equation routine problems required students to identify key information and employ appropriate problem-solving processes. The problems were arranged in increasing levels of difficulty, reflecting the progression of concepts in the secondary school mathematics curriculum. They were structured to promote productive thinking, and the problems aligned with Mayer's model of problem-

solving, namely translation, integration, planning, and execution phases. The duration of the interview sessions was at least 45 minutes for each participant.

2.5. Reliability and Validity

The validity of the instruments was established by reviewing two mathematics education experts to assess content, construct, and face components. Following necessary revisions, the items were pilot-tested on a separate group of 50 students to evaluate reliability. Notably, the participants in the pilot group were not included in the actual study sample (Singh, 2022). Using the school's nominal roll, 50 participants representing thirteen percent (13%) of the sample were randomly selected.

After obtaining approval from the school authorities, the questionnaires were distributed with the assistance of two teachers from the school. Participants were encouraged to complete the questionnaire honestly and sincerely. All 50 distributed questionnaires were completed and returned within the specified timeframe. In this study, rigorous research protocols were followed to minimize biases and errors, thereby enhancing the reliability of the findings with a high level of internal consistency of Cronbach's alpha coefficient of 0.801.

2.6. Ethical Consideration

The researchers obtained an introductory letter from the University and a consent form. The headmasters willingly assented to the request and issued acceptance letters, thereby granting permission for data collection. These acceptance letters facilitated the commencement of data collection.

With consent from the Headmasters, the Heads of the Mathematics Departments of the participating schools received appropriate notification about the study. Data collection took place over one week at the three schools on different days. The research questionnaires were personally administered to the students, and responses were collected immediately upon completion. This approach ensured a 100% response rate.

The participants were not compelled to take part against their will, as neither the researcher nor the school administration enforced participation. While the teachers aiding the researchers did not receive direct benefits, the insights gleaned from the study could potentially inform their teaching approaches. No incentives, monetary or otherwise, were offered to participants to prevent any inadvertent influence on their decision to join.

To ensure anonymity, participants refrained from including their names on the questionnaires, which were assigned unique codes for easy tracking of mathematics performance. The data was exclusively used for the study's purposes and was disposed of afterward. Participants' concerns were also prioritized, and they were given the option to halt questionnaire completion if they experienced any discomfort.

2.7. Method of Data Analysis

The SPSS software was used to concurrently analyze both the quantitative and qualitative data. Research Questions 1 and 2 used means, frequencies, and percentages to summarize the data. Cross-tabulations and frequency distributions were utilized to explore the relationships between these variables and students' proficiency in word problem solutions involving linear equations (Aja et al., 2025). Research Questions 3 and 4 explored means, frequencies, percentages, and themes based on the scripts. The content analysis was employed on the qualitative data, where students' worksheets were transcribed and pasted in the relevant areas. This supported and confirmed the results of the quantitative statistics.

3. RESULTS AND DISCUSSION

3.1. Translating Non-Routine Linear Word Problems

The participants responded to eight attitudinal items using the Likert scale. The responses were categorized and summarised in Table 2.

Table 2. Percentages of Translating Linear Word Problems

Statements	Disagree		Not Decided		Agree	
	N	%	N	%	N	%
Positive Items						
I have a lot of self-confidence when I am solving Linear Equation Word Problems	173	49.4	21	6.0	156	44.6
Linear Equation Word Problems do not scare me at all	187	53.4	21	6.0	142	40.6
I enjoy solving Linear Equation Word Problems	189	54.0	23	6.6	138	39.4
I fully understand Linear Equation Word Problems	153	43.7	63	18.0	134	38.3
Negative Items						
Most Linear Equation Word Problems are too hard to solve	56	16.0	18	5.1	276	78.9
I do not like solving Linear Equation Word Problems	153	43.7	18	5.1	179	51.1
I am always under a terrible strain when solving Linear Equation Word Problems	121	34.6	38	10.9	191	54.6
I find Linear Equation Word Problems very difficult	150	42.9	14	4.0	186	53.1

Table 2 shows that nearly half of the respondents (49.4%) disagree that they possess a lot of self-confidence when dealing with problems, while a significant proportion (44.6%) agree. Similarly, a majority of respondents (53.4%) express disagreement with the idea that problems do not scare them at all, while 40.6% agree. Moreover, the majority (54.0%) disagree that they enjoy solving problems more than any other math topic, with 39.4% agreeing. However, a notable percentage (6.0% to 6.6%) of students remain undecided about these positive statements.

On the contrary, a significant majority (78.9%) agree that most problems are too hard to solve, while only a minority (16.0%) disagrees. Similarly, a majority (51.1%) agree that they dislike solving problems due to past low scores, compared to 43.7% who disagree. Additionally, over half of the respondents (54.6%) agree that they experience strain when solving problems, while fewer (34.6%) disagree. Likewise, a significant majority (53.1%) agree that they find problems difficult regardless of effort, contrasting with 42.9% who disagree. In these negative statements, the percentage of undecided students ranges from 4.0% to 10.9%.

In essence, the results underscore the diverse perspectives students hold towards non-routine problems, with a significant portion agreeing with negative statements regarding difficulty and strain. However, the presence of undecided responses across both positive and negative statements highlights the complexity of translating non-routine linear word problems.

Table 3. Descriptive Statistics in Translating Linear Word Problems

Statements	Mean (M)	SD
Positive Items		
I have a lot of self-confidence when I am solving Linear Equation Word Problems	2.29	0.55
Linear Equation Word Problems do not scare me at all	2.22	0.58
I enjoy solving Linear Equation Word Problems more than any other topic	2.20	0.60
Usually, I fully understand Linear Equation Word Problems	2.06	0.72
Negative Items		
Most Linear Equation Word Problems are too hard to solve	1.93	0.82
I always scored low marks on them	2.09	0.74
I am always under a terrible strain when solving Linear Equation Word Problems	1.88	0.82
No matter how hard I try, I find Linear Equation Word Problems very difficult	2.02	0.73

The results in Table 3 indicate that students exhibit a moderate to high level of self-confidence when translating non-routine linear problems (Mean = 2.29, standard deviation = 0.55). Similarly, they tend to express moderate levels of fearlessness (M = 2.22, SD = 0.58) and Enjoyment of solving (M = 2.20, SD = 0.60). However, they moderately understand the solutions (M = 2.06, SD = 0.72). The negative perceptions reveal that students perceived difficulty (M = 1.93, SD = 0.82), expressed dislike (M = 2.09, SD = 0.74), levels of strain (M = 1.88, SD = 0.82), and feelings of discomfort (M = 2.02, SD = 0.73) were equally moderate. In short, while students generally hold moderate translation, there is considerable variability in

their perceptions and experiences, particularly concerning the difficulty and strain associated with solving them.

Table 4. The Proportion of Students Translating Linear Word Problems

Attitude Type	Number of Students	%
Negative Attitude	184	52.6
Positive Attitude	166	47.4
Total	350	100

Table 4 reveals that 52.6% of students exhibited a negative translation, while 47.4% demonstrated a positive one. This indicates skepticism towards translating non-routine problems was possibly due to perceived difficulty or disinterest. Therefore, educators and policymakers should address any challenges and leverage positive attitudes toward translating linear word problems. Essentially, educators can create more inclusive and effective learning environments that support student engagement and scaffolding.

3.2. Integrating Linear Word Problems

In this section, both routine and non-routine linear word problems were marked out of 20 each. Table 5 presents the proportion of students’ performance.

Table 5. Descriptive Statistics of Integrating Linear Word Problems

Statistic	Routine	Non-routine
Mean	18.15	5.88
Median	19.00	7.00
Mode	20	0
Std. Deviation	2.44	3.71
Range	11.00	13.00
Minimum	9.00	.00
Maximum	20.00	13.00

Table 5 distinguishes between routine and non-routine linear word problems. The results indicate that the mean score for routine problems stands at 18.15, contrasting with 5.88 for non-routine, indicating a notably higher average performance in routine problems. This trend persists with the modal score of 20 underscores as a common score in routine problems, whereas all scores are unique in non-routine problems. The variability analysis further elucidates the differences, with a lower standard deviation for routine problems (2.44) compared to non-routine (3.71), hinting at greater consistency in scores for routine problems, while the range for routine problems (11.00) proves narrower than that of non-routine problems (13.00).

The minimum score for routine problems registers at 9.00, while for non-routine problems it was 0.00. Conversely, the maximum score for both routine and non-routine problems stands at 20.00 and 13.00, respectively. In essence, the analysis highlights pronounced disparities in student performance between routine and non-routine linear equation problems, with routine problems showcasing higher average scores and less variability compared to non-routine problems.

Table 6. Percentile Performance of Students Integrating Linear Word Problems

	Routine	Non-Routine
Minimum	9.00	.00
Maximum	20.00	13.00
Percentiles		
25	18.00	4.00
50	19.00	7.00
75	20.00	9.00
95	20.00	11.00

Table 6 delineates between routine and non-routine problems. At the 25th percentile, students scored 18.00 on routine problems and 4.00 on non-routine problems, indicating the performance level of students

In Figure 4, the student struggled to identify the Least Common Multiple necessary for multiplying to clear the fraction.

3. $3(a - 2) = a + 8$, what is the value of a ?

$3a - 2 = a + 8$

$3a + a = 8 + 2$ NO

$2a = \frac{10}{3} = a = \frac{5}{10}$

Figure 5. Errors in Opening the Bracket

In Figure 5, the student overlooked multiplying 3 outside the bracket by -2 inside the bracket to obtain -6 as a term. In addition, there was an error in the expansion of the bracket; instead of writing $3a - 6 = a + 8$, they obtained $3a - 2 = a + 8$.

$5(m+4) = 35$

$5m + 20 = 35$ NO

$5m = 35 + 20$ NO

$\frac{5m}{5} = \frac{55}{5}$ NO

$m = 11$

Figure 6. Error in Grouping Terms

In Figure 6, the student accurately expanded the bracket but failed to group like terms correctly. Thus, they incorrectly obtained $5m = 35 + 20$ instead of $5m = 35 - 20$.

3.3.2. Executing Linear Word Problems

The execution involves selecting relevant information from the problem text and logically representing the problem as a whole, including identifying relationships between variables. The solution execution entails carrying out the planned computations to solve the problem. Consequently, the proportion and percentage of students who were unable to solve each of the five in Table 8.

Table 8. Proportion of students solving linear word problems

Solution Process	Q6		Q7		Q8		Q9		Q10	
	N	%	N	%	N	%	N	%	N	%
Defining variables	276	79	325	93	322	92	329	94	262	75
Correct expression	259	74	322	92	301	86	343	98	280	80
Finding the value of a variable	266	76	329	94	318	91	350	100	308	88
Opening of brackets	325	93			259	74	346	99	308	88
Grouping of like terms	245	70	332	95	311	89	350	100	308	88
Multiplying to clear a fraction			304	87						
Stating the correct answer	290	83	332	95	332	95	350	100	308	88

Table 7 shows the proportion of students unable to execute the solution in non-routine problems (Q6 to Q10). A high percentage of students struggled with defining variables (Q9 = 94%), and the lowest (Q10 = 75%). Writing correct mathematical expressions posed a significant challenge in Q9 (98%) and the least in Q6 (74%). Finding the value of a variable peaked at 100% in Q9 and was least in Q6 (76%).

The skill of opening brackets was assessed in Q6, Q8, Q9, and Q10, with the highest in Q9 (99%) and the least in Q8 (74%). Correct grouping of like terms was highest in Q9 and Q10 (100%), and lowest in Q6 (70%). Multiplying through to clear fractions was 87% in Q6. Students unable to state the correct answer were highest in Q9 (100%) and lowest in Q6 (83%).

In essence, we need targeted interventions in teaching and reinforcing these specific skills to improve student proficiency in solving non-routine problems. The consistently high percentages of errors across multiple skills and questions necessitate deeper scrutiny of the errors in Figures 7 to 10.

3.3.3. Scripts of Errors in Executing Linear Word Problems

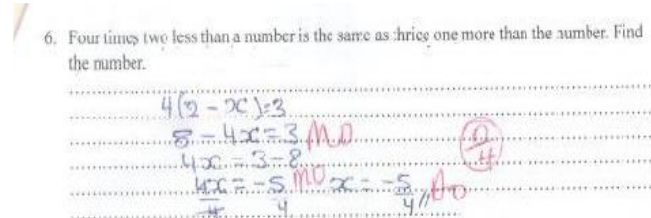


Figure 7. Failure to Define Variables

In Figure 7, the student failed to define any variable and did not follow Mayer's solution execution steps. They incorrectly obtained $4(2-x)$ instead of $4(x-2)$ for the expression *four times two less than a number*, and 3 instead of $3(x+1)$ for the expression *thrice one more than the number*. These errors were widespread in students' solution execution.

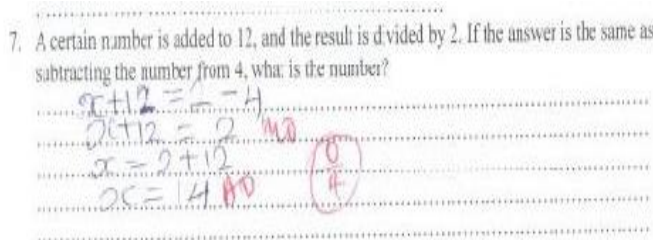


Figure 8. Lack of Variable Definition

In Figure 8, the student neglected to define a variable and divide the sum by 2. In the second part, the student mistakenly subtracted 4 from 2 instead of subtracting the unknown number (x) from 4. This certainly led to incorrect paraphrasing.

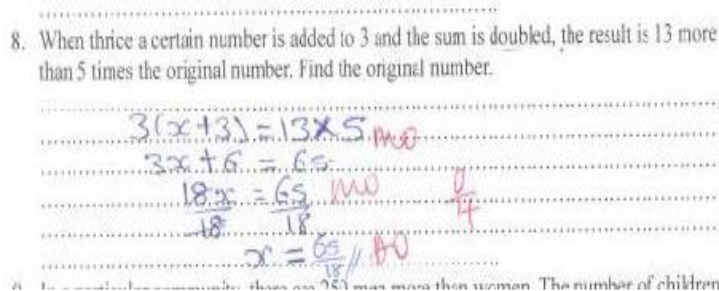


Figure 9. Errors with the Distributive Property

The student not only failed to define a variable and paraphrase the problem accurately, but also overlooked the product of 3 and a certain number. So, they incorrectly represented (13×5) for the expression *13 more than 5 times the original number* instead of $(5x + 13)$.

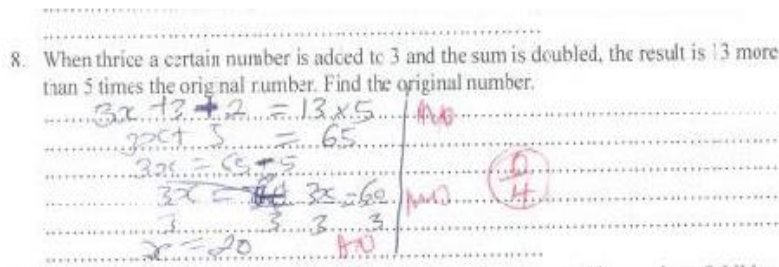


Figure 10. Lack of Variable Definition and Comprehension

The errors in the student's solution process in Figure 10 are evident in several aspects. Firstly, there was a failure to define variables properly, leading to ambiguity. Secondly, the student mistakenly added 2 to the left side of the equation instead of multiplying the sum $(3x + 3)$ by 2. Thirdly, there was an incorrect comprehension of the right side of the equation; instead of multiplying 13 by $5x$, the student multiplied 13 by 5. These errors collectively affected the execution of the problem accurately.

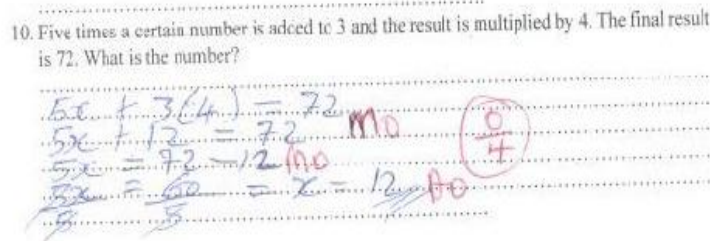


Figure 11. Lack of Variable Definition and Problem Integration Challenges

In Figure 11, the student failed to define any variable, leading to ambiguity; there was a lack of proper paraphrasing of the problem; they mistakenly multiplied 5 by the number (X) and added to (3×4) , equating it to 72, instead of correctly multiplying 5 by x , adding it to 3, and then multiplying the whole result by 4 and equating it to 72, as in $(5x + 3)4 = 72$. Although the students recognized the involvement of *five times a number* and understood that the process should yield 72, they struggled to express it correctly.

3.4. Mayer's Levels of Problem Solving

The performance of students at the various levels of Mayer's model of problem-solving is indicated in Table 8.

Table 8. Number of Items Solved with Mayer's Model

Levels	None	%	1 or 2	%	3 or 4	%	All 5	%
Problem Translation	224	64	102	29	21	6	3	1
Problem Integration	221	63	95	27	31	9	3	1
	None of 10	%	Less than 5	%	More 5	%	All 10	%
Solution Planning	21	6	255	73	74	21	0	0
Solution Execution	38	11	259	74	53	15	0	0

Table 8 presents the number and percentage of students' achievements across various levels of Mayer's Model of Problem Solving. In the category of "Problem Translation", 224 students (64%) could not correctly translate any of the five questions, and only 3 students (1%) did. In the "Problem Integration", 221 students (63%) could not correctly integrate any of the five questions, and only 3 students (1%) integrated the questions. In the "Solution Planning and Monitoring", 21 students (6%) could not plan and monitor any of the ten items, and no students (0%) could plan and monitor. In the "Solution Execution", 38 students (11%) could not execute solutions, and no students (0%) executed solutions for any item.

The results indicate substantial challenges across all levels of Mayer's model (Ofem et al., 2024). Arifin and Jupri (2025) supported that students often have challenges in transferring their procedural knowledge into meaningful solutions due to persistent gaps in integrating conceptual understanding, strategic reasoning, and metacognitive evaluation. Most students struggled, particularly with problem translation and problem integration, where over 60% could not correctly answer any of the questions. These findings underscore the necessity for improved instructional strategies to enhance students' problem-solving skills at each stage of Mayer's model.

4. DISCUSSION

4.1. Translating Linear Word Problems

The analysis of students' translation of Linear Equation Problems reveals a nuanced perspective (Wakhata et al., 2024; Rembert et al., 2019). For instance, nearly half of the respondents (49.4%) disagreed on self-confidence, while 44.6% agreed on self-confidence. However, self-confidence and proficiency play crucial roles in mathematics (Aja et al., 2025). Without self-confidence, students avoid challenging tasks and reinforce negative perceptions of linear word problems (Rembert et al., 2019). It was discovered that the translation phase chalked the most success because the students commonly use drawing of figures or diagrams, reasoning, and working tasks in typical problem-solving scenarios (Rizos & Gkrekas, 2024). This is commonly found in most Mayer's models, Polya's framework, or schema theory (Ofem et al., 2024).

The split choice on fearlessness by the majority (53.4%) disagreement and minority (40.6%) agreement suggests that translating linear word problems comes with a certain level of emotional responses, fear, and interest. This can impact engagement, persistence, and resilience in linear problems. This further induces intimidation, anxiety, and low morale. It behooves educators to cultivate a more resilient and confident approach to mathematical linear word problem-solving to navigate complex problem-solving tasks effectively and efficiently (Rembert et al., 2019).

Additionally, a majority (54.0%) disagreed with enjoying linear word problems, and a minority (39.4%) agreed. Interest (Rembert et al., 2019) and patience (Moleko & Mosimege, 2020) keep students working on linear word problems until they succeed, to guarantee their self-reward and preservation. The mean scores and standard deviations indicated that students generally exhibited moderate attitudes to translating linear word problems, but there was considerable variability in the perceived difficulty and strain. Teachers and policymakers should redesign targeted interventions while leveraging positive attitudes toward linear word problems (Leow & Kaur, 2024).

On the negative statements, the findings revealed that a significant majority (78.9%) agree, while only a minority (16.0%) disagrees that translating linear word problems is too hard to solve. Similarly, over half (51.1%) disliked it as compared to 43.7% who did not like the translation of linear word problems. This corroborates Hunt and Maloney's (2022) findings of students who disliked linear word problems due to lasting fear and decreased interest.

A significant majority (53.1%) found linear word problems difficult, as opposed to 42.9%. These students perceive mathematics as challenging and unmanageable, irrespective of their efforts to overcome difficulties (Rembert et al., 2019). The broader context of the debate is the persistence of mathematics anxiety and the perception of insurmountable difficulty (Rembert et al., 2019). Hunt and Maloney (2022) attribute negative experiences to the canker. These findings underscore the need for educational strategies that address both emotional and cognitive learning (Ofem et al., 2024).

Educators and policymakers must consider strategies to improve students' skills in linear word problems through positive reinforcement, encouragement, confidence, targeted support, and learning resources (Lillis, 2024). Mayer's model of problem translation fosters a growth mindset and improvement rather than innate ability. Ultimately, by adopting the model, educators can empower students with linear word problems and mathematical proficiency (Moleko & Mosimege, 2020).

4.2. Integrating Linear Word Problems

The mean score for routine (18.15) was significantly higher than for non-routine (5.88), indicating that students perform better on routine problem-solving tasks. This trend was further justified by the modal score of 20 for routine problems. The narrower range and lower standard deviation in routine problems suggest greater consistency in performance compared to the non-routine word problems (Qetrani et al., 2021). These disparities are due to the straightforward calculations and procedural tasks in routine problems (Qetrani et al., 2021).

In contrast, non-routine problems require reading comprehension, mathematical expressions, and multiple simultaneous conceptions. These additional steps tend to overwhelm students with weaker reading skills or lower mathematical self-efficacy (Kablan & Uğur, 2020). Even the integration of language and

mathematics in word problems can be too laborious (Qetrani et al., 2021). Educators might consider using explicit instruction for breaking down and integrating the words into solvable mathematical equations, step-by-step guidance, and scaffolded practice to reach the peak of complexity.

Students who excel in routine problems often struggle with non-routine problems. But the theoretical applications of Mayer's model hugely rely on contextual learning, real-world contexts, and meaningful learning that make the theory relevant to everyday life, and collaborate, encourage group work and discussion to share different ideas, and foster a deeper comprehension (Baidoo & Ali, 2024; Gavaz et al., 2021). Integrating the strategies improves students' ability to extract relevant information and incorporate diagrams, charts, and other visual aids in the milieu (Krawitz et al., 2021).

4.3. Planning Linear Word Problems

In the planning phase, the results revealed significant variations in proficiency across different non-routine problems. Some students successfully group like terms, simplify expressions, open brackets, multiply to clear fractions, and find variable values. The common errors emanated from defining variables, writing correct mathematical expressions, finding variable values, and performing other essential tasks across different questions. Capone et al. (2021) and Verschaffel et al. (2020) support targeted interventions, Leow and Kaur (2024) used manipulatives, Taley (2022) called for a conceptual internal representation of comprehension, and Verschaffel et al. (2020) recommend integrated planning strategies. By addressing these specific errors students encounter, Mayer's planning levels will ultimately improve their competency in non-routine problems (Ali, 2023).

Educators should plan tailored-made Mayer strategies to improve (Capone et al., 2021; Madzorera & Essien, 2018). Capone et al. (2021) discussed differentiated instruction and called for timely reinforcement to foster a more balanced and comprehensive understanding.

4.4. Executing Linear Word Problems

The errors observed in the problem execution phase were inaccuracies in defining variables, misinterpretations of mathematical expressions, failure to apply appropriate operations, and failure to accurately paraphrase problems (Ali, 2023). Taley (2022) ascribes barriers that students face in effectively navigating non-routine linear problems. This will enable students to grasp and correctly interpret the underlying concepts within the problems. The practical applications of Mayer's model bear on educators' explicit instructions on variable definitions and mathematical expressions to enable students to practise guided tasks, collaborative activities, targeted instruction, and conceptual clarity.

The execution required an improved Mayer model to enhance students' problem-solving skills. Even though Tay and Toh (2023) proposed Polya's (1945) and Schoenfeld's (1985) problem-solving models, educators should target interventions that focus on developing specific cognitive and metacognitive abilities required for this phase (Ofem et al., 2024). Mayer's model spells out explicit instruction, metacognitive strategies, setting goals, evaluating strategies, and adjustments. Collaborative learning, discussing approaches, sharing strategies, and peer tutoring could enhance patterns of problem execution (Rizos & Gkrekas, 2024).

5. CONCLUSIONS

First, the negative attitudes in non-routine linear problems require targeted interventions to address varying proficiency, conceptual misunderstandings, and errors. Secondly, the errors in grouping terms, simplifying expressions, and finding variable values tend to lower students' self-confidence, competence, and algebraic manipulation skills. Thirdly, the planning phase arose with massive errors in defining variables, misinterpretations of problem statements, and applying mathematical operations. These conceptual misunderstandings should be focused on improving overall performance. Lastly, the problem execution phase calls for fundamental skills in carrying out linear word problems to minimize errors. This should tailor educational approaches to meet the specific needs and competencies of students.

6. LIMITATIONS OF THE STUDY

The sample of 350 respondents, divided into 200 and 150 for experimental and control groups, respectively, posed sampling challenges. These results are from incomplete blocking, and clear procedures to minimize internal threats to validity. The convergent design was too simplistic to clearly show how the four phases of the model really converge. This was evident in the different rates of performance of the students in each of the phases.

Based on the findings, conclusions, and limitations, the following recommendations were made:

- To instill positive attitudes toward problem translation, it was recommended that targeted implementations of interventions focus on strengthening fundamental algebraic skills.
- To improve knowledge in the integration phase, it was recommended that linear word problems should be comprehensive, holistic, multidisciplinary, transdisciplinary, and interdisciplinary.
- To minimize errors in the planning phase, it was recommended that teachers address grouping terms, simplifying expressions, and solving for variables.
- To minimize errors in the problem execution phase, it was recommended that conceptual clarity should address inaccurate variable definitions, misinterpretations of problem statements, and incorrect mathematical operations.

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