Students' Error in Solving Percentage Word Problems: An Analysis by Using Newman's Procedure

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ARTICLE INFO

Received : 03 Jul. 2025
Revised : 27 Jul. 2025
Accepted : 19 Aug. 2025

Abstract

Students frequently struggle while solving the problem in the percentage, beside the common use of this skill in educational and daily lives. The descriptive analysis of the randomly selected answer-sheets collected from the four students of grade IX revealed the errors committed by the participants in solving a verbal problem on percentage calculation. In the analyses of the solutions attempted by the students' showed that many students demonstrated the transformation errors in misunderstandings regarding the percentage and its relationships in understanding of arithmetic aptitudes. The students seemed to have perceived the concept of percentage increase in additive and then multiplicative processes highlighting the errors when calculating the original values from the increased amount. In this research paper, the researcher examined the understanding of students' problems related to percentage appropriating Newman's Error Analysis (NEA) framework. This paper contributes in enhancing mathematics education by exploring the conceptual challenges in resolving percentage problems. It also recommends the effective instructional approach to address explicitly the ontological transition from additive to multiplicative reasoning. Further, this research addresses the cognitive effect in the mind of students that contradicts existing mental models and focused in restructuring the precise conceptual frameworks.

Keywords: *error analysis, Newman's error analysis, percentage problems, transformation errors, word problem*

Introduction

The researcher in mathematics education have found the complications of the problems occurs while solving problems related to percentage, Particularly, students are problems in increases or decreases in the values (Davis & Simmt, 2016). These type of problems occur in the teaching of concrete and categorical issues like percentage calculations. The indicative process of determining the conceptual difficulties rather than simple procedural errors (Geiger et al., 2018) as suggested by Newman's Error Analysis (NEA) framework. This framework offers a structured technique for tackling these problems by categorizing the students' mistakes into different stages: reading, comprehension, transformation, process skills, and encoding (Newman, 1977). Some researchers have observed the students' translation of verbal problem with appropriate mathematical equations as a notable obstacle while attempting the percentage problems and exposing fundamental misunderstandings of mathematical relationships (Scaptura et al., 2007; Van Galen & Van Eerde, 2013).

Mathematics education faces different challenges in enhancing students' conceptual understanding, apart from fostering procedural skills on percentage problems. Students are

familiar with percentages prior to their formal entrance into school (Van Galen et al., 2008; Van Den Heuvel-Panhuizen, 2003). Thus, there is some interest for learning them in the course of their education. Nonetheless, various investigations have highlighted that the learners frequently cope with difficulties while solving percentage problems (Parker & Leinhardt, 1995; Scaptura et al., 2007; Van Den Heuvel-Panhuizen, 2003; Van Galen & Van Eerde, 2013). Nevertheless, the precise instructions on percentage calculations, the learners remains struggling with the verbal problems. The analysis was principally focused on the pedagogical approaches that prioritize memorizing processes for resolving percentage issues. The simulating a conceptual comprehension as a long-term strategy for diagnosing the issue (Ngu et al., 2014; Rianasari et al., 2012 ; Van Galen & Van Eerde, 2013). There is no relationship between the procedural skills and the conceptual comprehension that gives consistent errors hinders proficiency in mathematical skill of percentage. This research investigates the significantly insufficient of understanding in the precise characteristics of student's errors in percentage problems, which is essential for creating and focusing the strategies there by enhancing mathematical, reasoning and problem-solving skills. Although the studies have documented common difficulties found in percentages (Parker & Leinhardt, 1995; Scaptura et al., 2007), the less attention has been given to specific types of conceptual errors resulting in the consistent transformation. The numerous students have algorithmic knowledge without conceptual understanding, this study examines the students' transformation errors occurs in basic misunderstandings regarding the mathematical connection between the original and increased values. This purpose of this research is to identify errors in students' responses to percentage problems that needs backward reasoning to find the original value from an increased amount. This analysis can inform targeted instructional strategies in mathematics education. In this context, this study has used the Newman's Error Analysis framework (Newman, 1977) to explore the different type of errors in the calculation of percentage. To achieve the research objectives focusing on mathematical misconceptions and creating specific instructional recommendations for enhancing understanding of the percentage and its relationships. To achieve the research goal, the following research questions have been determined.

What particular types of errors do students show at various stages of Newman's Error Analysis framework while solving percentage problems?

Use of Conceptual Change Theory in Mathematics Education

The conceptual change theory clarifies the influence of foundational knowledge in learning and the certainty of reorganize the frameworks of existing knowledge to attain a valid understanding. It gives the outlines that emerges learning through a significant reformation of a learner's cognitive structures instead of simple incorporation of updated information (Posner & Gertzog, 1982). This process includes in recognizing the insufficient existing cognitive knowledge, feeling their disagreement, and then upgrading the understanding with an accurate conceptual insight. For an effective conceptual change, the learners must perceive novel conceptions as a clear and trustworthy advantageous for providing larger illustrative strength than their preceding beliefs.

In the filed of mathematics education, it is crucial for a conceptual shift to take place concerning the word problems on percentage of the students often approach such challenges with a pre-existing and inadequate understandings of what the concept of percentages is signify. According to Vosniadou and Verschaffel (2004), gaining mathematical skill frequently requires to the learners' engagement in significant restructuring of mathematical concept, instead of achieveing simple knowledge. Many learners apply the formulas intuitively without understanding the relationships in mathematical knowledge. Lamon's (2007) expansion of this theory to

proportional reasoning proposed that students tackle conceptual barriers, when their intuitive mathematical concepts contradict with formal mathematical structures. The errors identified in the transformation phase as the similar view of Chi and Slotta's (1993). The concept of ontological categorization, where the students incorrectly categorize relationship of percentage as an additive instead of multiplicative constructs, encouraging reliable transformation errors despite the procedural competence in calculations.

Methodology

This study adapted a descriptive research design to observe the students' errors in resolving verbal problems on percentage through Newman's Procedure. A community secondary school at Kathmandu district was selected randomly as the research site for this study. The researchers purposely selected answer sheets, of Grade IX students, that had incorrect answers to the problems. It was discovered that 60% of the pupils (51 out of 85) committed mistakes while attempting the solution of the problem. Amongst these 51 incorrect answers sheets, the researchers randomly selected 4 answer sheets for the purpose of analyzing different type of errors. These sample answer sheets were assigned with codes S1, S2, S3, and S4. Focusing and initiating the study, the researchers has taken consent from the head teacher and the subject teacher determining the preservation of their confidentiality throughout the research.

Moreover, the research tools were confirmed by the consultation with experts of two professors of mathematics education and senior mathematics teachers with experiences 15 and 20 years to ensure validity. The researchers further took necessary steps to reduce potential biases during the analysis stages. The analysis of data followed Newman's error analysis steps, providing a structured approach for identification and classification of the various types of errors made by students, comprising reading, comprehension, transformation, process, and encoding**.** By adopting the well**-**established method, the researchers were enabled to identify the patterns in the students' mathematical misunderstandings and difficulties in resolving the verbal problems on percentage, which could guide targeted the instructional approaches.

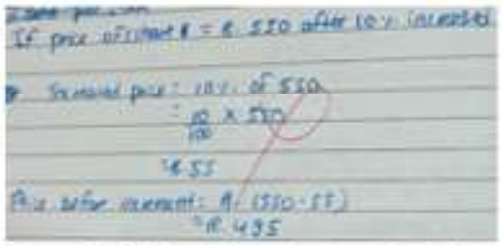
Results and Discussion

Under this section, the responses of the four students to the given questions have been discussed. The answer by each of the four students was examined based on Newman Error Analysis procedures and the researchers' findings on the concerned answer sheets of the students**.** Figure 1 describes the given problem, whereas Figure 2, 3, 4, and 5 represent the answers by students S_1, S_2, S_3, and S_4 respectively, along with the researchers' remarks. Student 1 (S_1) focused on a concerning change in the method of solving mathematics problems related to percentage. Though it appeared to acknowledge the appropriate proportional relationship of the concept on percentage. At first it was established the formula by reporting the amount from the raised amount. It later discarded this approach in favor of solving the equation $(550 \times 100)/110$, which gives the correct answer mathematically. It is shifted in calculating a percentage decrease percentage in 550 (i.e 10% of 550). This error highlights a fundamental misunderstanding of the link between an initial value and its percentage increase. Although it reached the correct answer of 495, this seemed to be coincidental event instead of reducing from sound mathematical reasoning. The work lacked the accuracy that required to show the understanding of the proportional relationship.

Figure 1: *Word Problem*

Question

If the price of a share of a bank is Rs. 550 after increment, what was the price before increment?



Researchers' Observation:

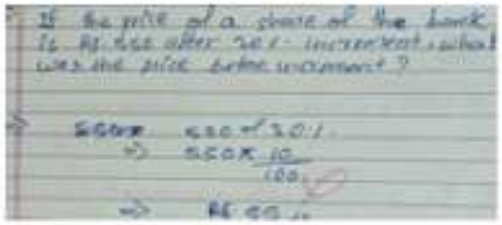
Failed to maintain a coherent mathematical approach; inconsistent algebraic reasoning.

Figure 2. *Solution of Question by student S1*

Researchers' Observation:

Fundamental misconception about percentage relationships; failed to compute correct answer

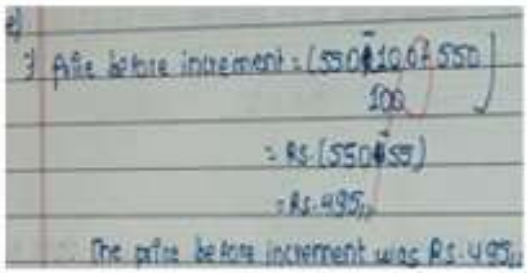
Figure 3. *Solution of Question by student S2*



Researchers' Observation:

Complete misinterpretation of the problem; added percentage to already increased value

Figure 4. *Solution of Question by student S3*



Researchers' Observation:

Applied incorrect mathematical relationship; failed to understand the relation between original and final price.

Figure 5. *Solution of Question by student S4*

Student S_2 demonstrated a significant misunderstanding of the increase in percentage. By indicating and then reducing the final price by 10% would result in the original price, a frequent important misunderstanding. The crossed-out sections indicated some uncertainty regarding the method where they ultimately moved forward with this faulty reasoning. For example: if x represents the original price, then 1.1x = 550, to be computed for x. So, the student S_2 used the

sum and manipulated it incorrect, showed an insufficient comprehending of percentage increase in original and concluding value mathematically.

Student S3 demonstrated the high level of conceptual confusion than other three students. S3's computes [(550 × 10)/100 + 550 = 605)] considering 550 as the initial price instead of the inflated price. Such basic misunderstanding went on to deviate the correct answer due to increase in the provided value by 10%, resulting to a total of Rs. 605/-. The failure in recognition of value indicated the presence of confusion in calculation of percentage, which is a critical misunderstanding in solution process.

Similar to student S2, student S4 presented with issue in percentage calculation. Despite correct calculation of 10% of 550 as 55, determination of original price went wrong due to incorrect subtraction of this value by 550. This highlights a major mistaken belief that the relationship between the original and increased values can be found by simple deduction of the percentage amount. While the student gave the correct answer of Rs. 495, their approach however did not seem to reflect an understanding of the proper algebraic relationship, where the final value represents 110% of the initial value (i.e., 1.1 times the original amount). This result shows that there is a significant conceptual gap in comprehending percentage problem.

The results revealed that the lack of complete comprehension and accurate execution of the percentage problem by sample students. Student S_1, who appeared to establish the correct method initially, with the correct algebraic steps and ended up with an inaccurate final answer that coincidentally aligned with the outcomes of the wrong process. The most common error was the improper transformation of the problem into mathematical expressions. Three students incorrectly deducted 10% from the final price, while one student increased the final price by 10%. Among these, none of the students accurately utilized the correct mathematical equation (original price × 1.1 = 550), which would result in the right answer of Rs. 500. However, none of the students accurately utilized this mathematical relationship, leading to the wrong answer of Rs. 495 (rather than Rs. 500 in three cases. The Table 1 presents a summary of Newman's error analysis for the students.

Table 1.
Newman Error Analysis of Student Solutions

Student	Comprehension	Transformation	Process Skills	Encoding	Remarks
S1	Understood the problem	Started with correct formula but abandoned it	Mixed approaches: (550 × 100/100) × 55 then switched to 550 - 55 = 495.	Arrived at the incorrect answer of Rs. 495	Failed to maintain a coherent mathematical approach; inconsistent algebraic reasoning

S2	Understood what was asked	Used incorrect relationship: final price minus 10% of final price	Correctly calculated 10% of 550 as 55 Correctly subtracted: 550 - 55 = 495. Conceptually wrong approach	Answer of Rs. 495 based on faulty reasoning	Fundamental misconception about percentage relationships; failed to recognize that if 1.1x = 550, then x = 550/1.1 = 500
S3	Misunderstood what "after 10% increment" means	Set up completely incorrect equation: price = 550 + (550 × 10/100)	Correctly calculated 10% of 550 as 55 Correctly added: 55 + 550 = 605 Wrong operation for the problem	Incorrect answer of Rs. 605	Complete misinterpretation of the problem; added percentage to already increased value
S4	Basic understanding present	Incorrect approach: subtracting 10% of final price	Correctly calculated 10% of 550 as Rs. 55 Correctly subtracted: 550 - 55 = 495 Conceptually wrong approach	Incorrect answer of Rs. 495	Applied incorrect mathematical relationship; failed to understand that original price × 1.1 = final price

As presented in the above Table 1 it was shown that the specific mistakes at every stage of the problem solving and focused the major misunderstandings in their methods. The analysis of the solutions of four students' answer sheet to determine the error in a percentage problem extracts consistent errors at multiple stages of mathematical problem solving. While ‘reading’ is the initial step in Newman’s Analysis Process, the researchers skipped the first stage and examined the participants’ answer sheets. During the comprehension stage, three students exhibited a foundational understanding of the problem, whereas one student fundamentally misinterpreted the meaning for 10% increment. The main problems appeared during the transformation stage, where all four participants did not accurately determine the mathematical relationship between the original and the increased prices. Three students incorrectly deducted 10% from the final price, whereas one student added 10% to the already increased amount. These transformation miscalculations or error related to process errors, as the learners conducted calculations based on incorrect mathematical setups, though their arithmetic operations were mostly correct.

Three students reached the same incorrect answer (Rs. 495 in place of Rs. 500), in the encoding stage, which reinforces how similar misconception may lead to continuation of errors.

The main problem behind such error was a primary misinterpretation of percentage relationships. To be specific, without realizing that if *1.1x = 550*, then *x = 550/1.1 = 500*. None of them rechecked their final answer. This analysis implicates how it is necessary to have an emphasis primarily on conceptual understanding of students and conversion of verbal problems to mathematical equation rather than just fluent calculative process.

The obtained results present with a consistency of transformation errors in students' answer in solving percentage problems, aligning with NEA framework. Three of the students presented with elementary understanding of problem but proceeded onto transformation error with the verbal problem. The primary misunderstanding is taking the percentage problem to be as additive or subtraction problem when it is multiplicative one. This was particularly by students S_2 and S_4 who took the original price by deducting 10% of the final amount (550 - 55 = 495). Chi and Slotta (1993) mention this as a ontological miss-categorization students who started with procedurally correct methods and discarded their valid strategies as demonstrated by S_1 by indicating weak conceptual foundations. It used the cognitive trials of backward reasoning in solving the percentage problems.

Interpreting this transformation error through the Theory of Conceptual Change, it highlights the need for change in cognitive understanding than mere knowledge acquisition. Due to this presence of cognitive conflict when faced with problems that necessitate backward reasoning, arise. According to Vosniadou and Verschaffel (2004), learning mathematics requires considerable conceptual restructuring, and the findings suggest that students lack the essential conceptual transition from additive to multiplicative reasoning within percentage contexts. This aligns to principal of conceptual barriers as suggested by Lamon's (2007). Where as the intuitive mathematical ideas contradicted with the formal mathematical structures. The didactic message is obvious instructional methods that should directly confront these conceptual obstacles by making cognitive conflict that raised the questions related to students' present mental models and supports in precise conceptual structures for grasping percentage relationships. The attitudes of teachers for the growth of quality of life and interest-driven learning helps to reduce the errors in mathematics (Ghimire, 2025). This establishes the students' concentration on mastering basic teaching aptitudes by minimizing the errors.

Effective learning occurs when the learners experience a conceptual shift, transitioning from viewing percentages as isolated processes to understand them as representations of proportional relationships related to various quantities (Paudel, 2023). This adjustment enables the learners to represent percentage in the flexible situation. Considering them conceptually, and resolve the solution of problems by the precise relationships between quantities that simply applying memorized procedures. In the context of percentage problem, the students should switch their intuitive additive reasoning concept into multiplicative reasoning structures as a fundamental conceptual transition (Moss & Case, 1999). Thus, teaching mathematics must emphasize the conceptual understanding, incorporate different representations, adopt regular diagnostic assessment to identify the specific stage. Whereas the student encounter difficulties, and incorporate the reflective practice to encourage students. They verify their answers is sensible or not in the original context of the problems.

Conclusion

The appraisal of four students' responses to a verbal problem on percentage by using Newman's Error Analysis (NEA) framework exhibited the majority of students comprehended the fundamental requirements of the problem, they predominantly faced challenges with transformation, the essential phase of converting the verbal problems into mathematical

relationships. The repeated error of deducting a percentage from the final value indicated a prevalent conceptual confusion regarding percentage relationships. Three students reaching at the same incorrect answer through identical inconsistent reasoning demonstrated the conceptual misconceptions could result in predictable patterned error. These results were consistent with the previous studies of students frequent errors in the use of procedural knowledge without a relevant conceptual understanding, especially in the domain of percentages and proportional reasoning.

This study implies that during teaching learning process conversion processes should be focused on rather than calculation process i.e. word problem to mathematical expression and vice versa. The recurrent error patterns mentioned in the article also imply the interventions are required for the specific misunderstanding, which leads to significant improvements in the students' accomplishment. The analysis of error that have significant insights for development of curriculum and support to measure in serving as an assessment tool. Furthermore, this also gives a window to the learners' cognitive processes. By addressing these fundamental and theoretical challenges in the percentage problems, educators could support the students in building strong mathematical reasoning aptitudes that transfer throughout the variety of the problems.

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