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Assessment of Higher-Order Thinking Skills in Algebra Concepts among Secondary School Students in Gusau Metropolis, Zamfara State, Nigeria

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Abstract

Higher-order thinking skills (HOTS) are essential for developing students' capacity to recognize patterns, reason critically, and apply mathematical concepts to real-world problems; however, empirical evidence on these competencies in secondary-school algebra remains limited in Gusau Metropolis, Zamfara State, Nigeria. This study aims to assess HOTS in algebra among secondary school students, focusing on pattern recognition, critical thinking, and mathematical modelling of real-world problems. A descriptive survey research design was employed with a sample of 60 Senior Secondary School I (SS I) students selected from two secondary schools, with 30 students drawn from each school through simple random sampling using the hat-draw method. Data were collected using a researcher-developed 15-item questionnaire comprising five items for each HOTS dimension. The instrument was validated by two mathematics lecturers and demonstrated satisfactory internal consistency, with a Cronbach's alpha coefficient of 0.83. Responses were measured on a four-point scale and analyzed using frequencies, percentages, means, standard deviations, and one-sample t-tests at the 0.05 significance level. The findings revealed statistically significant results for pattern recognition ($t = 20.676$, $df = 59$, $p < 0.001$), critical thinking ($t = 21.450$, $df = 59$, $p < 0.001$), and mathematical modelling of real-world

problems ($t = 23.607$, $df = 59$, $p < 0.001$), leading to the rejection of all three null hypotheses. Descriptive results further showed mean ratings of 2.86 for both pattern recognition and critical thinking and 2.93 for mathematical modelling, indicating generally positive responses across the three dimensions. The study concludes that students demonstrated positive outcomes across the assessed dimensions of HOTS in algebra. These findings highlight the importance of incorporating algebraic activities that require students to identify and generalize patterns, explain and justify mathematical reasoning, and formulate, solve, and interpret mathematical models based on real-life situations. The study contributes to mathematics education by providing empirical evidence on key dimensions of algebraic HOTS and underscores the need for continuous professional development to strengthen teachers' capacity to design and assess higher-order mathematical thinking tasks.

Keywords: Algebraic Thinking; Critical Thinking; Higher-Order Thinking Skills; Mathematical Modelling; Pattern Recognition

INTRODUCTION

Higher-order thinking skills (HOTS) refer to forms of thinking that require learners to use knowledge in ways that go beyond simple recall. In mathematics, these include analysing relationships, evaluating procedures or arguments, recognising patterns, making generalisations, and applying mathematical ideas to unfamiliar or real-world situations. Brookhart (2010) emphasises that higher-order thinking is closely associated with transfer, critical thinking and problem solving. These capacities are particularly relevant to algebra because algebra requires learners to interpret symbols, identify relationships, generalise patterns and construct models.

Assessment is central to the development and monitoring of these capacities. When assessment tasks require students only to reproduce procedures, they may provide limited evidence about whether learners can reason with mathematical ideas. Recent mathematics-education research has therefore given increasing attention to the design and use of assessment tasks that make higher-order thinking visible. Azid et al. (2022), for example, reported that incorporating HOTS into school-based mathematics assessment was associated with mathematics achievement and also identified challenges related to students' maturity and misconceptions. Similarly, Aydin and Birgili (2023) found that many mathematics assessment items examined in their study placed considerable emphasis on

automated computational skills, raising questions about alignment between curriculum goals and higher-order thinking.

Algebra provides a particularly useful context for studying HOTS. Pattern recognition is connected with mathematical ability across domains including algebra, while modelling requires learners to translate between real situations and mathematical representations. Ling and Loh (2023) found statistically significant relationships between pattern recognition and mathematical abilities in arithmetic, algebra and geometry. Edo and Tasik (2022) also demonstrated the importance of modelling tasks for understanding students' algebraic conceptual knowledge and problem-solving processes. In addition, validated instruments have been developed specifically to assess HOTS in algebraic content; for example, Kim How et al. (2022) developed the HOTS-QE instrument for quadratic equations and reported evidence of content validity and reliability. The Nigerian examination context also provides a practical justification for attention to higher-order mathematical thinking. The West African Examinations Council's 2023 General Mathematics Chief Examiner materials identify weaknesses including poor interpretation of questions and difficulty applying mathematical principles correctly, while recommending interactive teaching and the use of real-life cases. (West African Examinations Council, 2023) These observations reinforce the importance of examining how students respond to mathematical tasks that require interpretation and application rather than routine computation alone.

Although research on mathematical HOTS is growing internationally, locally situated evidence on specific dimensions of algebra-related HOTS among secondary school students in Gusau remains limited. Existing studies often examine general mathematics achievement, instructional approaches, or broader mathematical thinking, whereas the present study focuses on three dimensions—pattern recognition, critical thinking and modelling—within the local Gusau context. The study therefore provides context-specific descriptive evidence that can inform mathematics teaching and assessment in the study area.

Statement of the Problem

Algebra is fundamental to secondary school mathematics and provides a basis for later work in functions, equations, modelling and many STEM disciplines. However, success in algebra requires more than the ability to perform routine symbolic procedures.

Students also need to recognise patterns, reason critically about mathematical statements and use algebraic representations to interpret real-world situations.

The concern addressed in this study is that students may demonstrate competence in routine algebraic procedures while experiencing difficulty with tasks requiring interpretation, generalisation and application. This concern is consistent with the broader examination evidence reported by WAEC, including difficulties with interpretation and application of mathematical principles. (West African Examinations Council, 2023) At the same time, there is limited empirical evidence describing the level of these specific HOTS dimensions among secondary school students in Gusau Metropolis. The present study was therefore undertaken to assess students' responses in pattern recognition, critical thinking and modelling of real-world problems in algebra.

Objective of the study

The main objectives of this study are:

1) To assess the level of higher order thinking skills of students in critical thinking on algebra topics among secondary school students in Gusau.
2) To assess the level of higher order thinking skills of students in modelling real world problem (topics in algebra) in secondary school students in Gusau
3) To assess the level of higher order thinking skills on pattern recognition (topics in algebra) among secondary school students in Gusau

Research Questions

1. What is the level of assessment of HOT skill in algebra on critical thinking to secondary school students in Gusau
2. what is the level of assessment of HOT skill in algebra (modelling real world problem) to secondary school students in Gusau
3. what is the level of assessment of HOT skill in algebra (Pattern recognition) to secondary school students in Gusau

Research Hypotheses

1. There is no significance difference in the assessment of HOT skill in algebra (critical thinking) to secondary school students in Gusau
2. There is no significance difference in the assessment of HOT skill in algebra(modelling real world problem) to secondary school students in Gusau, Zamfara State

3. There is no significance difference in the assessment of HOT skill in algebra(pattern recognition)) to secondary school students in Gusau

METHODOLOGY

The study adopted a descriptive survey design because the purpose was to describe students' responses on selected dimensions of higher-order thinking in algebra rather than to determine the causal effect of an intervention. This design is consistent with the descriptive nature of the research questions. The study population comprised secondary school students in Gusau Local Government Area, Zamfara State, Nigeria. A total of 60 Senior Secondary I students were selected from two sampled schools: Government Girls Day Secondary School, Bye Pass, Tudun wada in Gusau and Sambo Secondary School, Gusau. Thirty SS I students were selected from each school. Simple random sampling was used and that a hat-draw procedure was employed to give eligible students an equal opportunity of selection. The total sample was therefore 60 students.Data were collected using a researcher-developed questionnaire designed around three dimensions of algebra-related HOTS: pattern recognition, critical thinking and modelling of real-world problems. The preserved manuscript contains 15 items, five items for each dimension, with responses recorded on a four-point scale: Strongly Agree (4), Agree (3), Disagree (2) and Strongly Disagree (1). The instrument was validated by two lecturers in the Department of Mathematics Ahmadu Bello University, Zaria, Nigeria. Its reliability was assessed using Cronbach's alpha, which yielded a coefficient of 0.83, indicating satisfactory internal consistency. The researcher personally administered the questionnaire to students in the sampled schools after the instrument had been validated. The completed questionnaires were used for the descriptive analysis. Means and standard deviations were used to summarise responses to the research questions. A response mean of 2.50 was used only as a descriptive midpoint for interpreting the four-point scale: means above 2.50 indicate generally favourable agreement with the statement, while means below 2.50 indicate generally unfavourable responses.

RESULTS

Bio-data information

Table 1: Sex of respondents

Sex	Number of Respondents	Percentage
Male	30	50%
Female	30	50%
Total	60	100%

Table 1 shows that the respondents are evenly distributed by sex, with 30 males (50%) and 30 females (50%), making a total of 60 respondents (100%).

Table 2 Marital status of respondents

Marital status	Number of Respondents	Percentage
Married	10	16.7%
Single	50	83.3%
Total	**60**	100%

Table 2 reveals that the majority of respondents are single, accounting for 50 individuals (83.3%), while 10 respondents (16.7%) are married, out of a total of 60 respondents (100%).

Table 3 Class of respondents

Class	Number of Respondents	Percentage
SSI	60	100%
SSII	0	0%
SSIII	0	0%
Total	60	100%

Table 3 indicates that all the respondents (100%) are in SS1, with no respondents from SS2 (0%) or SS3 (0%), making a total of 60 respondents.

RQ1: What is the level of assessment of HOT skill in algebra (Pattern Recognition?)

In order to answer this research question, statements on level of assessment of HOT skill in algebra (Pattern Recognition)were provided for the respondents to tick anyone they assent to. Table 4 presented the data collected and analyzed.

Table 4: Mean Score of Respondents on level of assessment of HOT skill in algebra (Pattern Recognition)

S/N	Item statement	SA	A	D	SD	Mean	Std dev.	Decision
1	The next three terms in the sequence 2,5,8,11,14 are 17,20,23	24	24	4	8	3.47	1.09	Agreed
2	When x=0,1,2,3- - -, The equation that represent the pattern 1,3,5,7,9,…is y =2x +1	15	25	14	6	3.23	1.13	Agreed
3	X | y 1 | 2 2 | 4 3 | 6 4 | 8 The relationship in the above table is y= 2x	19	18	12	11	3.05	1.25	Agreed
4	Consider the sequence 2,4,6,8 -------, The difference between the third and the first term is 4.	22	14	8	16	2.93	1.35	Agreed
5	The next three prime number in 2,3,5,7----- are 11,13,17	25	18	7	10	3.27	1.21	Agreed
Cumulative mean						**3.19**	**1.21**	**Agreed**

Source:Field Survey, 2024

Table 4 provides analysis of respondents' assessment of higher-order thinking (HOT) skills in algebra, specifically in pattern recognition. Item 1 shows that respondents agreed that the next three terms in the sequence 2,5,8,11,14 are 17,20,23with a mean score of 3.47 and a standard deviation of 1.09, indicating a strong consensus. Item 2 indicated that respondents also agreed that when x=0,1,2,3- - -, The equation that represent the pattern 1,3,5,7,9,…is y =2x +1, with a mean score of 3.23 and a standard deviation of 1.13. Item 3 revealed that the relationshipy= 2x is correctand was agreed upon by respondents, with a mean score of 3.05 and a standard deviation of 1.25. Item 4 revealed that respondents agreed that the difference between the third and first terms in the sequence 2,4,6,8,..is 4, with a mean score of 2.93 and a standard deviation of 1.35. While still above the threshold, this item had the lowest mean score. Item 5 revealed that respondents agreed that the next three prime numbers in the sequence 2,3,5,7 are 11,13,17with a mean score of 3.27 and a standard deviation of 1.21. The cumulative mean score of 3.19 indicates an overall positive assessment of respondents' HOT skills in algebra, with a standard deviation of 1.21 reflecting moderate variability in responses.

RQ2: What is the level of assessment of HOT skill in algebra (critical thinking) to student?

In order to answer this research question, statements on level of assessment of HOT skill in algebra (critical thinking)were provided for the respondents to tick anyone they assent to. Table 5 presented the data collected and analysed.

Table 5: Mean Score of Respondents on level of assessment of HOT skill in algebra (critical thinking)

S/N	Item statement	SA	A	D	SD	Mean	Std dev.	Decision
6	A bakery sells 250loares of bread per day, The number of loafs of bread that would be sold in ten days would be 2500	35	16	5	4	3.63	0.90	Agreed
7	The solution to the equation 2x + 5 = 11is 3	15	17	19	9	2.92	1.21	Agreed
8	The value of x in $^{x}/_{4} + 2 = 5$ is 12	19	19	14	8	3.13	1.19	Agreed
9	The fraction $^{2}/_{6}$ and $^{5}/_{15}$ are equivalent.	22	16	11	11	3.08	1.25	Agreed
10	$11 \times x \times y \times x \times y$ is the same as $11x^2y^2$	18	16	14	12	2.93	1.27	Agreed
Cumulative mean						**3.14**	**1.16**	

Source:Field Survey, 2024

Table 5 presents analysis of respondents' level of assessment of higher-order thinking (HOT) skills in algebra, specifically in critical thinking. Item 6 shows that respondents agreed that a bakery selling 250 loaves of bread per day would sell 2,500 loaves in ten days, with a mean score of 3.63 and a standard deviation of 0.90, indicating strong agreement. Item 7 indicated that respondents agreed that the solution to the equation 2x + 5 = 11is 3, with a mean score of 2.92 and a standard deviation of 1.21. While agreed upon, this item had the second-lowest mean score. Item 8 revealed that Respondents agreed that the value of x in the equation x in $^{x}/_{4} + 2 = 5$ is 12 with a mean score of 3.13 and a standard deviation of 1.19. Item 9 confirmed that respondents agreed that the fractions The fraction $^{2}/_{6}$ and $^{5}/_{15}$ are equivalent. are equivalent, with a mean score of 3.08 and a standard deviation of 1.25. Item 10 displays that respondents agreed that the result of the expression The result of $11 \times x \times y \times x \times y$ is the same as $11x^2y^2$, with a mean score of 2.93 and a standard deviation of 1.27. This item had the lowest mean score. The cumulative mean score of 3.14 indicates an overall positive assessment of respondents' critical thinking skills in algebra, with a standard deviation of 1.16 reflecting moderate variability in responses.

RQ3: What is the level of assessment of HOT skill in algebra (modelling real world problem)?

In order to answer this research question, statements on level of assessment of HOT skill in algebra (modelling real world problem) were provided for the respondents to tick anyone they assent to. Table 6 presented the data collected and analysis.

Table 6: Mean Score of Respondents on level of assessment of HOT skill in algebra (modelling real world problem)

S/N	Item statement	SA	A	D	SD	Mean	Std dev.	Decision
11	The simplification of $8^{20}+8^{20}$ is 2^{61}	19	16	16	9	3.02	1.21	Agreed
12	Both John and Emma could face the same math problem such as if x + 2 = 4 the value of x is 2	23	21	15	1	3.45	.93	Agreed
13	Zee has $56 and Olivia has 8 times less, then Olivia has $7	14	19	19	8	2.97	1.19	Agreed
14	A toy is cost $2 5 toys will cost $10	25	22	8	5	3.48	1.02	Agreed
15	A school orders pencils in packs of 24. There will be 96 pencils in 4 packs	24	22	7	7	3.42	1.09	Agreed
Cumulative mean						**3.27**	**1.09**	

Source:Field Survey, 2024

Table 6 provides an item-by-item analysis of respondents' assessment of higher-order thinking (HOT) skills in algebra, specifically focusing on modeling real-world problems. Item 11 revealed that respondents agreed that the simplification is 2^{61}, with a mean score of 3.02 and a standard deviation of 1.21. Item 12 shows that respondents strongly agreed that both John and Emma could solve the same math problem and have the value of x *to be 2*, with a mean score of 3.45 and a standard deviation of 0.93. This item showed the highest consensus among respondents. Item 13 confirmed that respondents agreed that if Zee has $56 and Olivia has 8 times less, then Olivia has $7, with a mean score of 2.97 and a standard deviation of 1.19. This item had the lowest mean score. Item 14 revealed that respondents strongly agreed that if one toy costs $2, five toys will cost $10, with a mean score of 3.48 and a standard deviation of 1.02, indicating strong agreement. Item 15 indicated that respondents agreed that a school ordering pencils in packs of 24 will have 96 pencils in 4 packs, with a mean score of 3.42 and a standard deviation of 1.09. The cumulative mean score of 3.27 indicates a generally positive

assessment of respondents' ability to model real-world problems in algebra, with a standard deviation of 1.09 reflecting moderate variability in responses.

Hypotheses testing

This section presents the results of the analysis conducted in order to test the null hypotheses stated at $p \leq 0.05$ level of significance. The three null hypotheses were tested using inferential statistics of one sample t-test.

HO1: There is no significance difference in the assessment of HOT skill in algebra (Pattern Recognition)to student and their performance

This null hypothesis was tested using inferential statistics of one sample t-test. The result of the analysis is presented in Table 7.

Table 7: One sample t-test on significance difference in the assessment of HOT skill in algebra (Pattern Recognition) to student and their performance

Variable	N	Mean	Std. deviation	t-value	Df	p-value	Decision
HOT skill in algebra (Pattern Recognition)to student and their performance	60	3.19	1.21	20.676	59	0.000	Rejected

Note: The critical t-value at df = 59 is 2.000, with a significance level of $p < 0.05$.

The one-sample t-test results indicate a significant difference in the assessment of Higher-Order Thinking (HOT) skills in algebra (Pattern Recognition) and students' performance, with a sample size of 60, a mean score of 3.19, a standard deviation of 1.21, a t-value of 20.676, and a p-value of 0.000, which is less than the critical t-value of 2.000 at df=59 and $p<0.05$; therefore, the null hypothesis is rejected, confirming that HOT skills in algebra significantly influence students' performance.

HO2: There is no significance difference in the assessment of HOT skill in algebra (modelling real world problem) to student and their performance

This null hypothesis was tested using inferential statistics of one sample t-test. The result of the analysis is presented in Table 8.

Table 8: One sample t-test on significance difference in the assessment of HOT skill in algebra (modelling real world problem) to student and their performance

Variable	N	Mean	Std. deviation	t-value	Df	p-value	Decision
HOT skill in algebra (modelling real world problem) to student and their performance	60	314	1.16	21.450	59	0.000	Rejected

Note: The critical t-value at df = 59 is 2.000, with a significance level of $p < 0.05$.

The one-sample t-test results reveal a significant difference in the assessment of Higher-Order Thinking (HOT) skills in algebra (modeling real-world problems) and students' performance, with a sample size of 60, a mean score of 3.14, a standard deviation of 1.16, a calculated t-value of 21.450, and a p-value of 0.000, which is less than the critical t-value of 2.000 at df=59 and $p<0.05$; thus, the null hypothesis is rejected, indicating that HOT skills in algebra (modeling real-world problems) significantly influence students' performance.

HO3: There is no significance difference in the assessment of HOT skill in algebra (critical thinking) to student and their performance

This null hypothesis was tested using inferential statistics of one sample t-test. The result of the analysis is presented in Table 9.

Table 9: One sample t-test on significance difference in the assessment of HOT skill in algebra (critical thinking) to student and their performance

Variable	N	Mean	Std. deviation	t-value	Df	p-value	Decision
HOT skill in algebra (critical thinking) to student and their performance	60	327	1.09	23.607	59	0.000	Rejected

Note: The critical t-value at df = 59 is 2.000, with a significance level of $p < 0.05$.

The one-sample t-test results indicate a significant difference in the assessment of Higher-Order Thinking (HOT) skills in algebra (critical thinking) and students' performance, with a sample size of 60, a mean score of 3.27, a standard deviation of 1.09, a calculated t-value of 23.607, and a p-value of 0.000, which is less than the critical t-value of 2.000 at df=59 and $p<0.05$; therefore, the null hypothesis is rejected, demonstrating that HOT skills in algebra (critical thinking) significantly influence students' performance.

DISCUSSION

This study assessed the secondary school Students' higher order thinking skills on algebra in Zamfara state. From the analysis of results of hypotheses one, two and three, the following findings were discussed. The finding of hypothesis one in this study reveals that HOT skills in algebra, specifically pattern recognition, have a measurable and statistically significant influence on students' performance. The result of data analysis on hypothesis one illustrates that the $t = 20.676$, $df = 59$, $p = 0.000$, which indicates that the probability value (p) is less than the alpha level ($p < 0.05$). This showed that HOT skills in algebra, specifically pattern recognitionenhance students' academic outcomes. The finding of this study is in line with the findings of Lin and Yang (2018) who highlighted that students with strong pattern recognition skills demonstrated superior performance in algebraic problem-solving. The findings is supported by Ng and Lee (2019) who investigated the relationship between pattern recognition and academic achievement in mathematics. Their results demonstrated that students trained in identifying patterns achieved significantly higher scores in algebra tests compared to those who did not receive such training.

The finding of hypothesis two confirmed that HOT skills in algebra, specifically modeling real-world problems, significantly influence students' performance. The result of data analysis on hypotheses two illustrates that the $t = 21.450$, $df = 59$, $p = 0.000$, which indicates that the probability value (p) is less than the alpha level ($p < 0.05$). This shows that HOT skills in algebra, specifically modeling real-world problems play critical role in students' academic success. This finding corroborates with that of Boaler (2016) who emphasized that teaching algebra through real-world problem modeling enhances students' conceptual understanding and problem-solving abilities. The findings is also supported by Lesh and Zawojewski (2017) demonstrated that students who actively modeled real-world problems using algebra showed enhanced engagement and higher academic performance.

The result of hypotheses three established that HOT skills in algebra, particularly critical thinking, have a substantial and statistically significant impact on students' performance. The result of data analysis on hypotheses three shows that the $t = 2.607$, $df = 59$, $p = 0.000$, indicating that the probability value (p) is less than the alpha level ($p < 0.05$). This shows that HOT skills in algebra, particularly critical thinking enhance students' academic achievement. This finding lay credence to the finding of Staples and Truxaw (2022) found that fostering critical thinking in algebra classrooms significantly improves

students' performance. The findings is also supported by Sriraman (2021) who highlighted that critical thinking skills enable students to approach algebraic problems methodically, leading to better problem-solving outcomes.

CONCLUSION

The study has shown that lack of higher order thinking skills affect student's ability in handling mathematics concepts, now and in future, as we assessed their ability and result turned to be negative. This is clearly the devastating effect of student's poor background in HOT

Recommendations

State and National assessments are important since they serve the role of communicating what teacher should be teaching and how they should teach it as well and what students should be learning. The following are also recommended

1. Integrating of HOT skills into the curriculum,
2. The use of enquiry based learning by teachers,
3. Provision of ongoing training to the teachers,
4. Supporting teacher collaboration,
5. Recognizing and rewarding innovative teaching

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