Zamfara International Journal of Education (ZIJE)
The Official Journal of the Faculty of Education
Federal University Gusau, Zamfara State, Nigeria
Volume 6, Number 5, August, 2026
pISSN: (Hard Copy): 2814 – 1377; eISSN (Online): 2814 – 1369 www.foefugusau.com.ng
DOI: **https://doi.org/10.64348/zije.2026538**

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

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Abstract
The study assessed the secondary school students' higher order thinking skill on Algebra. Sixty (60) secondary school students. Questionnaires were used to collect data from the participating students. The population consists of all secondary school students in Gusau, Zamfara State in which sixty students were randomly selected from the sampled schools. Descriptive statistics were used to analyze the research questions while one sample t-test was used to test the null hypotheses. It is recommended among other things that State and National assessments are important since they serve the role of communicating what teacher should be teaching and how it should be thought and what students should be learning. Additionally, there is need for integrating of HOT skills into the curriculum, use of enquiry-based learning approach by the teacher, provision of ongoing training to the teachers and supporting teacher collaboration.
Keywords: Higher Order thinking Skills, Algebra, Students

Introduction
Teachers who plan to teach and extend student's higher order thinking skills promote growth for their high-ability students. Higher order thinking is often used to refer to 'transfer', 'critical thinking' and 'problem solving.' These can be defined as: transferring the student's ability to apply knowledge and skills to new contexts (for example, a student in year 5 learning about fractions applied her knowledge to a real world scenario) critical thinking - the ability to reason, reflect, and decide what to believe or do next and problem solving deals with meeting a goal that cannot be met with a memorized solution (Brookhart, 2010, 2011).

The incorporation of higher order thinking skills (HOTS) in school-based assessment (SBA) is assumed to potentially affect students' mathematical achievement. Thus, the findings of this study are expected to be useful for the relevant authorities to continuously improve and enhance mathematics learning and assessment activities in schools. Assessment is the practice of collecting, reviewing, and using information about educational programs systematically to improve student learning and development. Assessment can be considered as a systematic basis for making inferences on students' achievements. It is also about making judgments, identifying strengths and weaknesses, as well as right or wrong for an educational program, and it is more than giving marks or grades, although these are all part of the assessment. The role of assessment in any educational system is very important because it guides a teacher to choose learning tasks and approaches to optimize the use of those tasks. SBA is an effort to develop human capital holistically through emphasis on the mastery of knowledge, intellectual capital, cultivating a progressive attitude and the practice of high values, ethics and morals. It is a holistic assessment that assesses the cognitive (intellectual), affective (emotional and spiritual) and psychomotor (physical) aspects. The SBA is designed to lessen excessive dependence on scores and grades that students obtain through centralized examinations. SBA is expected to enhance the focus on student development as well as the development. Algebra is the part of mathematics that helps represent problems or situations in the form of mathematical expressions. In algebra, we use numbers like 2, −7, 0.068 etc., which have a definite or fixed value. In algebra we use variables like x, y, and z along with numbers. Algebra is the study of mathematical symbols and the rules or manipulating these symbols (Sari et al., 2021,p.46)

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Statement of the Problem

The study assessed student's abilities in algebra topics that require critical thinking, pattern recognition , and modeling of real world problem (Crodua,2022). This study aimed to evaluate the extent to which secondary school students can apply algebra to model real-life situation (U.S. Department of Education,2020).

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

Research Methodology

The research design for this study was a survey research method and it made use of a questionnaire to generate data from the respondents on the assessment of higher order thinking skills in algebra among senior secondary school students. The population of this study consist of all secondary schools in Gusau Local Government Area.Simple random sampling techniques was used to select a total of sixty (60) students from two sampled schools, the schools are Government Girls Day Secondary Bye pass, Tudunwada and Sambo Secondary School, Gusau. Thirty (30) SS 1 students were selected from each school making a total of sixty (60) students. The researcher used questionnaire as the instruments for data collection in relation to the research questions that are intended to draw information on the assessment of secondary school students' higher order thinking skills on algebra in Zamfara state.The instruments was validated by two lecturer in the department and Cronbach's alpha coefficient was calculated to obtain the reliability of the instruments.The procedure involved for collection of data for this research was questionnaire which was personally constructed by the researcher, validated and then taken to the sampled schools. The descriptive statistics using the mean and standard deviation was used to answer the research questions while the null hypothesis was tested using inferential statistics of one sample t-test.

Presentation of 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%).

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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. (U.S. Dept. of Educ. 2020)	24	24	4	8	3.47	1.09	Agreed
2	For the arithmetic sequence 1,3,5,7,…, the linear equation is y=2x+1 where x=0,1,2,.. (U.S. Dept. of Educ. 2020)	15	25	14	6	3.23	1.13	Agreed
3	X | y 1 | 2 2 | 4 3 | 6 4 | 8 In the table above the relationship in the above table is y= 2x. Crodua,2022	19	18	12	11	3.05	1.25	Agreed
4	In the sequence 2,4,6,8 -------, The difference between the third and the first term is 4. (U.S. Dept. of Educ.2020, p.12)	22	14	8	16	2.93	1.35	Agreed
5	The next three prime number in 2,3,5,7----- are 11,13,17. (U.S. Dept. of Educ.2020.)	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

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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

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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.

H_{O1}: 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.

H_{O2}: 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.

H_{O3}: There is no significance difference in the assessment of HOT skill in algebra (critical thinking) to student and their performance

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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 of findings

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 recognition enhance students' academic outcomes. The finding of this study is in line with the findings of Lin and Yang (2018) who highlighted those students with strong pattern recognition skills demonstrated superior performance in algebraic problem-solving. The findings was also 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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DOI: **https://doi.org/10.64348/zije.2026538**

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