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Research Article

Build and standardizing a test to measure number sense among first-year middle school pupils

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ABSTRACT

The current study aimed to build and standardize a test to measure the number sense of first-year middle school pupils in the city of Aflou, where the test was applied to a sample representing the original community, consisting of 710 male and female pupils, who were selected randomly in a multi-stage manner. To answer the study questions, the effectiveness of the test paragraphs was examined and its psychometric properties were verified, and then percentiles were derived as criteria for interpreting the raw scores on the test.

The study yielded the following results:

- The number sense test paragraphs enjoyed a high level of effectiveness.
- The numerical sense test has a single-factor structure, as it measures one trait.
- The test enjoyed psychometric properties that indicate its suitability for use on first-year middle school pupils.

Keywords: Standardization, the number sensetest.

1. Introduction:

The recent reforms in mathematics education have brought about a qualitative shift in how mathematics is taught and understood, as the focus in the educational process has shifted from mathematical operations and routine algorithms to mathematical structures, where this approach has enhanced a deep understanding of the basic concepts that form the basis of mathematics, and also supported the development of critical and logical thinking skills, and increased the ability of pupils to benefit from this knowledge in various fields, whether scientific, technical, or even in their daily lives.

This type of education enhances the ability to be creative and solve problems in new and unconventional ways, and accordingly, "the goal of teaching mathematics at all levels of education has become to understand concepts and deduce laws and relationships, in addition to acquiring or developing skills, and the broader and more comprehensive goal of all of this is to solve mathematical problems that arise from the pupil's real life"(NCTM, 1989.2000).

Among the most important resources that the learner should recruit, as it plays a crucial role in solving mathematical problems, we find number sense, considering that it enables pupils to estimate answers before starting to solve the problems, and it also enables them to employ different strategies based on the nature of the problem, which qualifies them to move smoothly between arithmetic operations, and develops their ability to understand the relationships between numbers and operations, such as how changing one of the numbers in a process affects the final result, which enhances their ability to deal with numbers in an effective way, to solve a problem situation or a class of problem situations.

2. Problem of the study

Mathematics is a strategic subject, as it gains its importance from the goals that educational systems seek to keep pace with rapid changes and transformations in various fields, therefore, education specialists and experts in Algeria are keen to review and develop mathematics curricula, to improve the deep understanding

of concepts and develop critical thinking skills and problem-solving strategies, which allows the pupil to acquire competencies of an intellectual and methodological nature, enabling him to acquire mechanisms that help him anticipate solving the problem as a mathematical activity, or shorten the path in searching for its solution.

This review resulted in the inclusion of number sense as an educational goal in the process of developing the contents of mathematical knowledge, and it refers to "a general deep understanding of numbers and operations on them, and the possibility of using this understanding in a flexible way to issue mathematical judgments, and develop special strategies to solve complex problems, away from the monotony of classical rules and procedures." (Ben Saad,2011, p. 7).
Number sense includes several components, the most important of which are: “perceiving the meaning and size of a number, explaining and representing the different values of a number, perceiving the relative effect of operations on numbers, perceiving and using equivalent mathematical expressions, and the ability to determine the appropriate mathematical relationship” (Hafedh, 2020, p. 417).
Accordingly, the modern educational approach in the field of mathematics in Algerian schools has focused on the nature of the process of learning and teaching mathematics by including number sense as a competency that the learner should acquire, through the integration of various educational activities that contribute to enhancing pupils' understanding of numbers, and the ability to use them effectively as an essential part of mathematical education, instead of focusing only on the learner's acquisition of rules and algorithmic procedures and their application in different situations.
Therefore, the mathematics curriculum recommends a set of strategies that take into account the status of mental arithmetic, to create a suitable environment for learning, which helps pupils develop numerical sense, as it emphasized the importance of highlighting these strategies for the status of problem solving as a mathematical activity, by proposing problems arising from the heart of his social environment, which allows the pupil to learn about numbers and operations and realize their significance, and the teacher's full awareness of the components of number sense, as it facilitates the pupil's dealing with the mechanisms and properties of the mathematical system.
Accordingly, it has become necessary to evaluate these strategies that contribute to the development of number sense, which requires evaluating these strategies by providing standardized tests to measure the levels of number sense among pupils.
The current research comes to keep pace with the educational reform in the field of mathematics, by providing a standardized test to be used in measuring the numerical sense of first-year middle school pupils on the one hand, and to evaluate the effectiveness of teaching strategies that contribute to the development of number sense, and proposed in the mathematics curriculum for the first year of middle school on the other hand, as there are no standardized tests that measure number sense in the Algerian environment. Accordingly, the current research seeks to answer the following questions:
- To what extent are the paragraphs of the test that was builded effective in measuring number sense, after applying it to first-year middle school pupils in the city of Aflou?
- Does the number sense test that was builded have stability coefficients that are consistent with the characteristics of a good test?
- Does the number sense test that was builded have validity indications that are consistent with the characteristics of a good test?
- What are the performance criteria for the number sense test that was builded, after applying it to first-year middle school pupils in the city of Aflou?

3. Research objectives:

The current research aims to build and standardize a test to measure the number sense of first-year middle school pupils. To achieve this goal, the research focused on the following:
- Examining the effectiveness of the number sense test items.
- Examining the psychometric test characteristics on first-year middle school pupils.
- Finding performance standards for the number sense test.

4. Importance of the research:

The importance of the current research is evident in the need of middle school institutions to have a test to measure number sense, to benefit in educational evaluation processes, and in selection and classification processes.

5. Procedural definitions

5.1. Number Sense: It means the flexibility and ease in employing non-routine arithmetic strategies, in dealing with fractional, relative and decimal numbers, and their perception and understanding of their meaning and the operations applied to them, which is measured by the number sense test that was built, through the score that the pupil obtains, which is interpreted through the percentile standards.

5.2. Standardization: means unifying the conditions and procedures for applying and correcting the number sense test that was built on first-year middle school pupils, as well as analyzing the effectiveness of its components, studying its psychometric properties and finding performance standards.

6. Building the number sense test

The test was built after analyzing the content of numerical activities within the mathematics curriculum for the first year of middle school, prepared by the Ministry of National Education, and based on the operational definition that was determined in light of some definitions that were used to clarify the concept of number sense in the theoretical aspect.

Among these definitions, we find the definition of (Saleh, 2001, p. 160), which he defines as a good understanding of the meanings of numbers, and includes the awareness of equivalent representations of them, as well as the awareness of the relative impact of performing operations on numbers and using arithmetic expressions consciously, and using measurement to derive new information, with the formation of effective strategies in managing arithmetic operations.

The definition provided by Al-Said, who believes that the general goal of studying the numerical system, regardless of its type and development, aims to develop flexible strategies among pupils in dealing with numbers and dealing with them to confront problems and life situations. (Al-Balawneh et al., 2012, p. 223)

(Metwally and Abdel Hamid) explain that number sense is the intellectual flexibility in dealing with numbers in terms ofrealizing the meaning of the number and its relationship to other numbers, the ability to perform mental arithmetic operations and make comparisons easily (Atifi, 2012, p. 212).

It is worth noting that most studies agreed in their definition of number sense, such as the study of (Bin Saad, 2011, p. 27), the study of (Yang, 2002, p. 153), and the study of (Eugene, 1999, p. 19) that it refers to flexibility in: dealing with numbers, realizing the number and understanding its meaning, using non-routine arithmetic strategies, comparisons between numbers and operations on numbers.

When formulating the test items, the components of number sense in the intermediate education stage were taken into consideration, as determined by (Ben Saad 2011, pp. 199-200), after reviewing many studies, where he confirmed that most of them almost agree on three basic components, which are:

- Flexibility in dealing with numbers: This includes understanding the meaning of numbers, using equivalent representations, and referring to signs.
- Flexibility in dealing with operations: understanding and using the properties of operations in calculations.
- Flexibility in dealing with numbers and operations: approximate estimation and calculation strategies.

7. Preparing the test paragraphs

Based on the elements of the final competencies of the numerical activities, which focused on natural numbers, decimal numbers, fractional numbers, and relative numbers, within the mathematics curriculum, and in light of the procedural definition and components of number sense, twenty-one paragraphs were constructed as a preliminary image of the test, which were presented to a group of teachers and primary education inspectors for review, based on the previous criteria in light of which they were built, through the arbitration form.

After emptying the arbitration forms, the researcher found that the arbitrators agreed on the contents of the test paragraphs and their number. Hence, the test obtained a content validity index through their agreement at rates of 100% that the numerical sense test paragraphs measure what they were designed to measure. The researchers attribute the reason for this agreement to our reliance on the assistance of three first-year middle school teachers in building the test, so that the number of test paragraphs became 21 paragraphs, of the multiple-choice type covering the components of number sense.

8. Formulating the test instructions:

The test instructions were formulated and placed on the first pages of the test, and included the following aspects:

- Procedures to encourage pupils to do their best in answering the test items.
- The pupil's personal identification data.
- A brief description of how to answer the test items.
- Examples of training

9. Correcting the test and estimating its score:

Correction is done in light of the correct answer model, where one (1) score is given for the correct answer to the item, while the wrong answer or abstention from answering the item is given a score of (0), then the scores are added to form the total score on the test, and accordingly the theoretical score on the test ranges between "0" and "21".

10. Field testing of the test:

After preparing the test, it was applied in several middle school institutions on a sample of first-year middle school pupils. Accordingly, this step resulted in the clarity of the test instructions, as shown by their answers,

and the time to answer the test was estimated at 17 minutes, by taking the sum of the time taken by the first pupil to complete the test, as well as the time taken by the last pupil to complete the test, divided by two.
After completing the exploratory study procedures, the researcher prepared the numbersense test, then was applied in several middle school institutions in the city of Aflou on a standardization sample of 710 male and female pupils from the first year of middle school in the 2023/2024 academic year, selected using a multi-stage random sampling method, from the current study community, which numbered 2755 male and female pupils, according to the following steps:
- Randomly drawn, seven middle schools out of 12 middle schools.
- Randomly drawn three sections of pupils from each middle school.

Study results:

1. Effectiveness of the numerical sense test paragraphs:

To answer the first question, the effectiveness of the test paragraphs in measuring number sense was examined, by calculating the difficulty, discrimination and variance coefficients for each test paragraph.

1.1. Difficulty Index:

The difficulty index for each paragraph of the number sense test was estimated, by calculating the percentage of those who answered the paragraph correctly, based on the performance of the standardization sample members, and the results are shown in the following table:

Table 01. Shows the values of the difficulty coefficients for the items of the numerical sense test.

Variable	Paragraph	Difficulty Factor	Paragraph	Difficulty Factor	Paragraph	Difficulty Factor
Number sense	01	0.37	08	0.32	15	0.30
	02	0.42	09	0.39	16	0.43
	03	0.40	10	0.30	17	0.32
	04	0.42	11	0.30	18	0.38
	05	0.37	12	0.34	19	0.32
	06	0.36	13	0.41	20	0.30
	07	0.30	14	0.29	21	0.43
Average Difficulty Factor: 0.35						

The table 01 shows that the values of the difficulty coefficients ranged from 0.29 to 0.43, with an average of 0.35, which means that the paragraphs were moderate in their ease and difficulty, and the test showed a good gradation in terms of difficulty, which is consistent with the purpose for which the test was prepared, to show a good degree of variance between the individuals targeted by the measurement process.

1.2. Discrimination Index:

To examine the discriminating ability of each paragraph of the number sense test, the special point bi-sequential correlation coefficient was calculated between the score of each paragraph and the total score on the test, based on the performance of the standardization sample individuals, and the values of the extracted discrimination coefficients were judged through Eble's criteria, as shown in the following table:

Table 02. Shows the values of discrimination coefficients for the items of the numerical sense test.

Variable	Paragraph	Discrimin. coefficient	Statistic. decision	Paragraph	Discrimin. coefficient	Statistic. decision	Paragraph	Discrimin. coefficient	Statist. decision
Number sense	01	0.56	very good	08	0.50	very good	15	0.64	very good
	02	0.55	very good	09	0.49	very good	16	0.60	very good
	03	0.61	very good	10	0.54	very good	17	0.64	very good
	04	0.59	very good	11	0.57	very good	18	0.58	very good
	05	0.61	very good	12	0.62	very good	19	0.70	very good
	06	0.64	very good	13	0.55	very good	20	0.67	very good
	07	0.66	very good	14	0.64	very good	21	0.57	very good
Average discrimination coefficient: 0.59									

We note from Table 02 that the discrimination coefficient values ranged from 0.49 to 0.70, with an average of 0.59, which means that all items of the number sense test enjoyed a very good evaluation based on Eble's criteria, and thus the test items provide an opportunity to distinguish between the targeted individuals.

1.3. Item Variance:

The variance of each item of the test was calculated by multiplying the value of the ease coefficient by the difficulty coefficient of the item, and the results showed that the variance values of the items ranged between 0.20 and 0.24, with an average of 0.22, which means that all items of the test enjoyed good variance, and were consistent with the test characteristic that included items of medium ease and difficulty, and the test did not include items of extreme ease or difficulty, and the results reached are shown in the following table:

Table 03. Shows the values of the variance coefficients of the items of the number sense test

Variable	Paragraph	value of the variance	Paragraph	value of the variance	Paragraph	value of the variance
Number sense	01	0.23	08	0.22	15	0.20
	02	0.24	09	0.23	16	0.24
	03	0.24	10	0.21	17	0.21
	04	0.24	11	0.21	18	0.23
	05	0.23	12	0.22	19	0.22
	06	0.22	13	0.24	20	0.21
	07	0.21	14	0.20	21	0.24
Average paragraph variance: 0.22						

2. Stability of the numerical sense test:

To answer the second question, the value of the stability coefficient was estimated after applying the number sense test to a sample of 84 male and female pupils, who were randomly drawn from the standardization sample, with a time interval of two weeks. The test was re-applied to the same sample members, then Pearson's correlation coefficient was calculated between their performance (scores) in the first application and their performance in the second application. The correlation coefficient showed that the value of the stability coefficient for the number sense test reached 0.949, as this value indicates that the test has high stability, which indicates the stability of the test and its ability to give the same results if it is re-applied to the same individuals, indicating the stability of the test in the current research community. The values of the test stability coefficients were also estimated by calculating the internal consistency coefficients, as the results showed that the test was characterized by high stability, and the value of the test stability coefficient using the split-half method reached 0.943, while the reliability coefficient using the Kuder Richardson formula 21 method reached 0.927, which is the same reliability value enjoyed by the test using the Cronbach's alpha method, which reached 0.928, indicating the homogeneity of the test items in measuring the numerical sense. The results are shown in the following table:

Table 04. Shows the values of the stability coefficients and internal consistency of the.

Variable	Stability coefficient	Kuder-Richardson coefficient -21	Cronbach's alpha coefficient	Split-half coefficient	Split-half coefficient correction
					Spearman Brown
Number sense	0.949	0.927	0.928	0.893	0.943

3. Validity of the number sense test:

To answer the third question, the validity of the number sense test was estimated through the following validity indicators:

3.1. Factorial validity:

To verify that the number sense test items contain a single-factor factor structure after applying it to the standardization sample, the researchers resorted to verifying the conditions of the exploratory factor analysis procedures, to know the extent to which the standardization sample data meet the conditions that allow the possibility of continuing the factor analysis procedures, and the following table shows the results:

Table 05. Shows the results of verifying the conditions for using the factor analysis procedure

Method	Value	Statisticalsignificance
Bartlett's Test Based on Chi-square value and its statistical significance	6031.35	0.000 statistically significant
Kaiser-Meyer-Olkin KMO test	0.961	greater than 0.70
MSA (Measure of Sampling Efficiency(	/	Its value exceeded the criterion estimated at 0.50, which means statistically significant.

The results of the indicators shown in Table 05 show that the correlation matrix consisting of 21 variables has the ability to be factor analyzed. Based on these indicators, exploratory factor analysis using the principal components method (PCA) was used, and the following table shows the results:

Table 06. Shows the value of the latent root of the extracted factor, and what it explains of the total variance and the saturation coefficients of the items on it.

Variable	Paragraph	Saturations on the general factor	Paragraph	Saturations on the general factor	Paragraph	Saturations on the general factor
Number sense	01	0.605	08	0.555	15	0.691
	02	0.594	09	0.532	16	0.643
	03	0.655	10	0.592	17	0692
	04	0.630	11	0.607	18	0.626
	05	0.660	12	0.674	19	0.699
	06	0.693	13	0.595	20	0.714
	07	0.699	14	0.694	21	0.625
Latent Root		8.697				
Explained Cumulative Ratio		%41.415				

Based on the latent root values, we note from Table 06 the presence of one general factor with a latent root value of 8.697, which explained 41.415% of the variance of the responses of the standardization sample members to the test. Therefore, it can be said that the measured variables shared a factor that explains the variance or the common denominator between them, which confirms that the factorial structure of the concept of number sense involves a single-factor structure, which gives an indication of the validity of the hypothetical formation (factorial validity).

3.2. Concurrent validity:

To find evidence of concurrent validity, the researchers resorted to calculating the Pearson correlation coefficient between the pupils' achievement scores (subject average) in mathematics and their scores on the numerical sense test, on a sample of 76 male and female pupils, drawn randomly from the standardization sample. The results showed that the test had a statistically significant correlation at a significance level of 0.01, with a value of 0.84, and the number sense test also showed a statistically significant correlation at a significance level of 0.01, with a value of 0.64 when calculating the Pearson correlation coefficient between the pupils' scores on the number sense test and their scores on the Cattell Intelligence Test, level two, on a sample of 84 male and female pupils, drawn randomly from the standardization sample, which indicates a degree of common variance between the number sense variable and the variables of academic achievement in mathematics and intelligence, which confirms that the number sense test has concurrent validity.

4. Performance criteria:

To answer the fourth question, the five main percentiles and their corresponding raw scores were found as performance criteria, in light of which the raw scores on the numerical sense test are interpreted. The percentile ranks corresponding to each score on the test were also found, and the results are shown in the following tables:

Table 07. Shows the five main percentile criteria for the number sense test and their corresponding raw scores.

Percentile Standards	95	90	75	50	25
Raw Scores	20	19	11	6	2

Table 08. Shows the raw scores of the number sense test and their corresponding percentile ranks.

Variable	Raw Score	Percentile Rank	Raw Score	Percentile Rank	Raw Score	Percentile Rank
Number sense	01	20.3	08	66.9	15	83.1
	02	26.8	09	71	16	84.2
	03	33.1	10	74.4	17	85.4
	04	39.6	11	77.7	18	87
	05	46.3	12	80.1	19	91.7
	06	53.1	13	81.4	20	95.8
	07	61.3	14	82.5	21	100

5. General conclusion:

Based on the results of the current study, the following was found:

- The paragraphs of the number sense test, after applying it to the first year middle school pupils, enjoy a high degree of effectiveness, as indicated by the quantitative indicators extracted from the use of difficulty coefficients, discrimination coefficients, and paragraph variance, which indicates the validity of the test for the purpose for which it was prepared, which is the evaluation processes and the selection and classification processes.
- After applying the numerical sense test to the first year middle school pupils, there are indicators of stability and validity that are consistent with the characteristics of a good test.
- The validity of employing the number sense test in evaluating, selecting and classifying pupils, through the use of the percentile criteria that were found.

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Appendix:

Number Sense Test

Test Instructions:

Dear Professor;

Before distributing the test to the pupils, start by encouraging them to do their best to answer the test questions, and make sure to convince them that the test is part of their assessment.

After distributing the test papers to the pupils, remind them to fill in the blank for personal identification information on the test document.
Then the training example is explained (in the test booklet), before you allow them to start answering all the test questions.
Dear Pupil;
After each question in the test, you will find four options. You are required to read the question carefully, then put an (x) in the correct answer boxes.

Training question:

Paragraph	A	B	C	D
(9+4) – (4+1)equals	**8**	**10**	**9 + 4 – 4 +1**	**9+1**

Test correction method:

1. Correction is done in light of the correct answer model, shown below.
2. The correct answer is given one mark (point), and this is done by placing an (x) in the box for the correct alternative or alternatives, and accordingly the maximum points is 21 points.
3. The points are collected and placed at the bottom of the answer sheet and are as follows:

Answer sheet for the number sense test

Name: ..... Test Date: ..... School.....

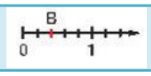
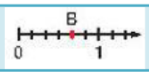
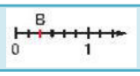
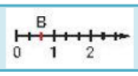
Question number	Answer alternatives				Question number	Answer alternatives			
	a	b	c	d		a	b	c	d
01					12				
02					13				
03					14				
04					15				
05					16				
06					17				
07					18				
08					19				
09					20				
10					21				
11									

Total points

Number sense test correction key

Question number	**Answer**				**Question number**	**Answer**			
	a	**b**	**c**	**d**		**a**	**b**	**c**	**d**
01	x	x		x	12		x		x
02	x		x		13	x	x		
03	x		x		14	x		x	
04	x	x			15	x		x	x
05		x	x		16	x		x	
06		x	x		17		x	x	x
07	x			x	18		x	x	
08	x	x		x	19	x		x	
09			x	x	20		x	x	
10		x	x		21	x			x
11	x			x					

Number sense test
Natural numbers and decimal numbers

Paragraph	a	b	c	d
1 For the number 42.125 The hundredths number is	One' digit	Half Tens digit	Twice the Thousandth digit	Twice the Tenth digit
2 The number 1.72 =	1720/1000	172/1000	172/100	172/10
3 6/1000 + 4/10 + 1=	0.006+0.4+1	1.046	1.406	1.46
4 The number 5.09 =	(0.01*9)+5	9/100+5	9/10+5	five and nine parts of a thousand
5 For the numbers 55.58 and 55.6 we can write	55.6<55.58	55.6>55.58	55.6≠55.58	55.58=55.6
6 For numbers 6.3, 6.03 and 6.13 we can write	6.13>6.3>6.03	6.3>6.13>6.03	6.03<6.13<6.3	6.13>6.03>3.6
For question 7, we consider a = 3.51126.				
7 The number a can be enclosed between the two numbers	3.6 and 3.51	3.5 and 3.4	4 and 3.6	2 and 5
Addition and subtraction of decimal numbers				
Paragraph	a	b	c	d
85.3+2.9+3.7=	11.9	2.9+9	10.9	2.9+5.3+3.7
95.975+12.4+3.89=	22.045	0+10+0	22	6+12+4
Multiply and divide decimal numbers				
Paragraph	a	b	c	d
103*4*2.1*0.25	12	2.1*3	6.3*1	6.1*1
1111.22*4.86=	11*5	44.8372	411	10*5
Fractional numbers writing				
Paragraph	a	b	c	d
12 In which case point B has a 2/3 interval?				
13 16/36=	32/72	8/18	8/12	1/3
14 5/4=	25/20	4/5	10/8	15/4
15 8 * 2/5=	5:(2*8)	5*(8:2)	2*(5:8)	8*(5:2)
Relative numbers				
Paragraph	a	b	c	d
16Numbers 5.4	Positivenumber	Negativenumber	Rationalnumber	Irrationalnumber
17The opposite of 2.8 is	Negativenumber	Positivenumber	2.8	+2.8
For questions 18 and 19 we use the following formula: 				
18 Distance to zero of point F	Negative	Distance OF	3	-3
19 Point D is	greater than point c	less than point c	Opposite of point G	Same point G
20Compare the numbers 6.3 and -5.7	-5.7<-6.3	-5.7>-6.3	-6.3 < -5.7	-6.3 > -5.7
21 Compare the numbers 1.4 and -2.5	-2.5 < 1.4	-2.5 > 1.4	1.4 < -2.5	1.4 > -2.5