Constructing a logical-mathematical intelligence test for ninth-grade students using item response theory

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ABSTRACT

Introduction. Intelligence tests are used to measure cognitive abilities, to assess individuals' strengths and weaknesses, and to identify areas where interventions or accommodation may be necessary. In addition to using it to compare the cognitive abilities of individuals with established standards and identify gifted students, Since the tests used in schools suffer from weaknesses, namely their inability to measure the full range of students' abilities and their weak ability to discriminate between students, in addition to the saturation of the content of these tests with tasks that depend on school experience and their reliance on classical theory in their construction. As a result of scientific and technological development and the development of software related to the applications of item response theory, which allows students' abilities to be estimated in an effective way that matches the difficulty of the item with the capabilities of individuals, as logical-mathematical intelligence is extremely important for students, as students have the ability to solve and analyze problems, As a result of the scarcity of standardized tests for logical-mathematical intelligence in the Jordanian environment, this study came about.

The problem and the aim of the study. The problem with the study is that the psychological and educational tests, including logical intelligence tests, used classical measurement theory in their construction, which suffers from weakness as this theory does not provide a psychological explanation that explains how the study subjects try to answer one of the items and how the characteristics of the item are affected by the ability of the respondents, and the lack of a fixed unit of measurement means the variance of measurement errors is equal for all examined. This study aimed to construct a test for logical-mathematical intelligence using item response theory that has reliable psychometric properties that enable teachers to detect the logical-mathematical intelligence of students.

Research methods. The study utilized a descriptive survey method, as well as the logical-mathematical intelligence test which described the difficulty, discrimination, and guessing parameters. The instrument consisted of (46) items and was validated by a panel of experts to ensure its reliability and content validity. The Bilog program as well as SPSS package were used to answer the study question. (260) ninth-grade students who attended both normal and gifted schools were selected according to a stratified random method in the first semester of 2023/2024, from gifted and regular schools in Jordan.

Results. The results indicated that the assumptions of the three-parameter model were met. The test also demonstrated acceptable validity the findings of the factor analysis indicated unidimensionality of the study instrument. The test reliability indicators showed an acceptable values as Cronbach alpha reached 0.87. As well, the estimations of the item parameters; discrimination, difficulty and guessing were satisfactory.

Conclusion. The study derives its importance from its use of one of the item response theory models, which is the three-parameter logistic model, which provides the opportunity to estimate the test parameters of difficulty, discrimination, and guessing, which gives the test efficiency and objectivity, in addition to the fact that this test may be used by researchers in the future for the purposes of scientific research.

KEYWORDS

test, logical-mathematical intelligence, ninth-grade students, item response theory

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INTRODUCTION

Global educational frameworks, such as UNESCO, advocate for the improvement of logical-mathematical intelligence, considered a crucial competency for academic success [1]. Logical-mathematical intelligence is a particularly important dimension of human intelligence. As a result of this type of intelligence, individuals are able to analyze data and information to find solutions to mathematical problems analytically. In order to develop the mental skills base required to achieve excellence in a variety of areas of life, it is imperative that one has a solid understanding of logical-mathematical intelligence.

An individual who has mathematical-logic intelligence has the ability to comprehend and analyze mathematical relationships and models logically and apply mathematics to problem-solving. Solving simple mathematical equations and reasoning are examples of demonstrating such intelligence.

Mathematics and logic play an important role in education, as they facilitate the understanding of complex mathematical concepts and can motivate students to improve their mental abilities. As a result of logically solving mathematical problems, academic excellence is enhanced, and a strong foundation for continuous learning can be built [2].

There are several aspects of daily life influenced by logical-mathematical intelligence, as individuals with this type of intelligence demonstrate an exceptional ability to solve complex problems in many different fields. It can also contribute to making sound decisions based on logical thinking, whether in personal or professional life, and researchers have recently demonstrated an increasing interest in the field of developing logical-mathematical intelligence. Despite the importance of logical-mathematical intelligence, researchers face difficulties in fully understanding it and developing effective strategies to improve it, despite the fact that studies demonstrate that training and exercise can contribute substantially to enhancing such intelligence, providing a new horizon for education and individual development. Taking into account current developments in the field of education, it is imperative that educational technologies and innovation be integrated into training programs that continuously enhance this intelligence.

A number of human endeavor’s domains require logical intelligences and mathematics to function in an effective way. What is more, researcher have faced a number of challenges in several fields that require analytical skills, such as economics and computer programming, can enhance and develop the capability of analyzing data and formulating conclusions. In order to improve productivity, this intelligence aims to enhance decision-making skills based on analysis and logic. In addition, science and mathematics skills that are demonstrated by students in the course of their learning and their careers can be correlated with logic-mathematical intelligence. Furthermore, a study by Aminah and Kusumah [3] indicated that researchers faced a number of challenges when they explored the relationship between neuropsychology and education, as understanding how logic-mathematical intelligence impacts individuals' lives is crucial to understanding it. Moreover, other researches have demonstrated that individuals with logic-mathematical intelligence types are more likely to respond effectively to everyday obstacles [4].

Furthermore, the ability to analyze data and formulate conclusions can be developed in a number of areas that require analytical skills, such as economic analysis, computer programming, and management. The purpose of this intelligence is to enhance performance by making well-informed decisions based on logic and analysis. Mathematics and science competencies demonstrated by students in the field of education as well as in their career and achieving success in various professions can be attributed to logic-mathematical intelligence.

Students who have a better understanding of mathematical concepts can interact more effectively in academic settings. However, traditional mathematical education may not be adequate to develop this type of intelligence fully. Thus, research studies have suggested that more innovative teaching methods are required to facilitate students' stimulation and interaction, to encourage their use of mathematics in their daily lives, and to improve their problem-solving skills [3].

THEORETICAL BACKGROUND

1. Logical-mathematical intelligence

It is possible to gain a deeper understanding of the relationship between logical-mathematical intelligences and other intelligences by reviewing Gardner's model of multiple intelligences. Individuals can benefit from the combination of multiple intelligences in one or more ways in order to enhance their comprehensive development. As a result of improving analytical and logical reasoning, it may enhance language comprehension and artistic expression. Thinking creatively and coming up with new ideas is possible with logic-mathematical intelligence. Using these analytical and mathematical skills, we are able to develop new technologies and innovate in society, ultimately resolving complex problems [5]. A person's ability to solve problems, both on an individual and social level, is influenced by his or her logical and mathematical skills, as well as genetics and environmental influences.

According to Gardner [6], deductive and inductive reasoning are used to accomplish mathematical tasks, solve logical problems, and analyze scientific topics. A logical intelligence is defined as the ability to use numbers efficiently, to think logically, to solve problems, to create new outcomes, and to understand theoretical and logical relationships (causes and effects). Among its primary ties are mathematics and science. In order to develop logical or procedural thinking, a child must have sufficient experience with concepts, organized in a coherent manner, to develop logical or procedural thinking, which Piaget refers to as operations or principles. Examples of these responses include logical intellectual processes, such as arithmetic operations, classifications, and arrangements, which have been absorbed. The process of rational thinking involves organizing the cognitive potential of an individual when confronted with a problem, often resulting in confusion, hesitation, or a need to think. Al-Gharaibeh [7] proposes an optimal alternative by adopting, analyzing, and comparing opinions, in order to limit the problem and reach an optimal alternative.

Jackson et al. [8] states that students with logical-mathematical intelligence are individuals who are proficient in numbers, possess innate skills in logic, problem solving, and creative thinking, and are skilled learners. With the use of multimedia technology, teachers can promote the development of students' logical-mathematical intelligence. In addition to the fact that logical-mathematical intelligence is one of the most important intelligences associated with mathematics, this relationship between logical-mathematical intelligence and learning mathematics is evident. In mathematics, numbers and figures are closely related and it focuses on measuring and estimating quantities and amounts. Furthermore, it is based on inference, deduction, analysis, synthesis, arrangement, and organization of different things in a precise, logical manner with specific characteristics [9].

2. Item Response Theory

In psychology and education, this theory represents the contemporary trend, and it is sometimes referred to as the latent trait theory or the item characteristic curve theory. As a result of this theory, the shortcomings and problems of the classical theory, which was the dominant theory in developing tests, were confronted and overcome [10]. A number of shortcomings of classical theory were not addressed by the theory, including the identification of bias in paragraphs and the equation between test scores. As part of the classical theory, there are several methods for estimating stability, including parallel forms, which are difficult to obtain, and repetition calculations. In addition to its disadvantages, this method can cause the examinee to forget. Based on mathematical models, IRT explains the relationship between the ability of the examinee and the likelihood of responding to the paragraph. Based on the examinee's ability and the parameters of the paragraph, IRT models indicate the probability of answering a paragraph. It is possible to use IRT models with two responses, such as multiple choice and multiple response paragraphs.

The polytomous IRT model can be explained using the mathematical image of each response. For example, when an item contains more than two responses, such as: solving mathematical problems. It is the Three-Parameter Logistic Model that is used in this study, as it is the most general of the two-parameter and single-parameter models, as it includes a third parameter, which is the estimation parameter, making it the most general of the two-parameter and single-parameter models. Using this model, three parameters are indicated: the difficulty of an item and its discrimination, as well as an estimation parameter that determines the likelihood that the examinee, whose ability level is assumed to be extremely low, will answer an item correctly through estimation. Consequently, the test paragraphs differ in terms of difficulty, discrimination, and estimation values, as indicated by the symbol "c". Based on the data obtained from the study sample, it was used in this study to estimate the probability of response and ability parameter most accurately.

3. Item Response Theory Models

The item response theory can be classified as parametric or non-parametric according to Cliff and Keats [11]. Consequently, each of the previous approaches proposes an underlying grading for particular abilities or personality traits, resulting in an increase in probability of correct responses with increasing ability [12] as one advances from a low ability subject to a high ability subject.

In order to construct response theory models for parametric items, a number of assumptions need to be taken into account. Unidimensionality is one assumption that suggests that the subject's performance can only be explained by a single characteristic or ability. In this regard, they are considered unidimensional models. However, multidimensional models, in which many abilities are assumed to underlie a particular performance, are considered multidimensional models, which assume local independence. According to this assumption, the responses of an individual to a given item are statistically independent, and that speed does not play a significant role in performance [12].

In the case that an individual fails the test, it is directly related to a decrease in their ability, rather than their speed. As a mathematical function, the Item Characteristic Curve is a mathematical function that directly links the probability of correctly responding to an item to a subject's ability, which can be assessed through a set of items or through a specific test. An individual's chances of answering correctly increase with the number of latent traits he possesses [13; 14].

4. Three-parameter logistic model

This model treats the Lower Asymptote Line or Guessing Parameter, which means that the subject answers the test items by guessing, randomly, or according to their knowledge, and takes the following mathematical formula into consideration:

$$Pi(\theta) = ci + \frac{(1- \mathrm{ci})}{1+\mathrm{e}^{-\mathrm{Dai}(\theta - \mathrm{bi})}} \tag{1}$$

Considering the ability of the subject (θ), there is a probability that the subject will answer item (i) correctly, and Pi(θ) represents the probability that the subject will answer item (i) correctly taking into account the ability of the subject. The bi indicates the difficulty parameter of the item, which corresponds to the point on the ability continuum where the slope of the characteristic curve is greatest for each test item. In addition to the scaling factor, which is approximately equal to (1.70), bi represents the difficulty parameter of the item. Item discrimination factors (i) are determined by the slope of the item curve. It is important to note that in this equation, ci represents the item guess factor (i) representing the probability of a subject guessing the answer correctly or randomly [12] or Lower Asymptote Line, which indicates convergence with the y-axis of the item characteristics curve.

PREVIOUS STUDIES

Several authors, including Purwitaningrum and Prahmana [2], emphasize the importance of instructional materials to the excitement and meaning of learning. These aspects of learning are often not sufficiently addressed by teachers, resulting in a disinterest in learning. As a result, the purpose of the research is to create instructional materials that will facilitate students' logical thinking of mathematics ability, as a result of Indonesian Realistic Mathematics Education. As part of this study, a design research method was utilized with a development study in two stages, preliminary design, followed by formative evaluation, which included self-evaluation and prototyping (expert reviews, one-on-one and small-group testing), conducted in a junior high school setting. Data collection for class VIII B students at a junior high school was conducted through documentation, walkthroughs, interviews, and tests. The research data is analyzed quantitatively and qualitatively. Based on the analysis of data, this study demonstrates that Indonesian Realistic Mathematics Education provides instruction materials that promote logical thinking in mathematics. The formulation of linear equations involving two variables is addressed in a way that is valid, feasible, and potentially effective, utilizing an effective model. It has been demonstrated that the content validity, constructiveness, and language validity of mathematics instruction in Indonesian Realistic Mathematics Education worksheets are valid. On the other hand, the math student worksheets derived from Indonesian Realistic Mathematics Education are based upon revisions conducted individually and in small groups. This can result in a positive effect on students' ability to think logically and to solve math problems as a result of the prototype of instructional materials in the form of worksheets.

A study conducted by Alnasraween [15] aimed at developing a digital culture test in light of IRT. The study sample consisted of (650) male and female students in Jordan. The findings indicated that the items had acceptable discriminating indicators and covered a suitable range of difficulty levels. Various methodologies, including content validity and internal consistency, were employed to assess the test's validity and reliability. According to the study's findings, the majority of the test items satisfied the assumptions of the two-parameter logistic model for the private sector. Furthermore, according to the item response theory, Olimat [16] developed a math achievement test consisting of 40 items for the twelfth grade. It was found that the hypotheses of the model were met, namely unidimensionality and local independence. The results also indicated that the test had high reliability (8.41). According to the results, the difficulty coefficient for the item ranged between (5.64-5.01) logit, and the discrimination coefficient ranged between (0.45-2.91) at a rate of 1.31. Moreover, based on the item response theory, Al-Anzi and Abdel-Aal [17] conducted a study aimed at developing a criterion-referenced test to assess the basic skills in mathematics for primary school graduates. A 32-item test was administered to 205 female sixth-grade students in the study. Based on the results, the assumptions of the model were met, and the reliability coefficient was 0.82 and the difficulty parameter ranged between -2.43 and -2.83.

In a study conducted by Aminah and Kusumah [3], a quasi-experiment was conducted to examine how metacognitive teaching-learning (MTL) and mathematical prior knowledge (MPK) influence students' ability to solve problems mathematically logically (MLTA) and self-regulate themselves. This study involved 70 ninth grade students from Sumenang, Indonesia. During the experimental group and control group, students were divided into three categories based on their prior mathematical knowledge levels (high, medium, and low). There were three types of MPK tests in this study: short answers, essay MLTA tests, and SRL tests. Data were analyzed using ANOVA, t-tests, Mann-Whitney tests, and Kruskal-Wallis tests. MTL showed superior results compared to conventional learning for students in the MLTA as well as SRL. The students have relatively good SRL scores in general, but their MLTA grades are still very low for the entire student body as a whole. In terms of MLTA, learning approaches and MPK do not interact, but there is a relationship between learning approaches and MPK on SRL.

Rohaeti& Budiyanto [18] examined how problem-based learning contributes to the development of students' mathematical reasoning capabilities and self-regulating learning skills through the use of problem-based learning. A master's thesis and a substudy of a 2013 DGHE Postgraduate Research Grant were undertaken for this study. In this study, 93 students from a Karawang senior high school were selected at random for a quasi-experimental control group design conducted pre-test and post-test. Several instruments were utilized in this study, including an essay test assessing mathematical logical thinking, a self-regulated learning scale, and a rating scale measuring students' perceptions of participatory learning. The students receiving PBL treatment achieved lower grades than students receiving conventional instruction but were more proficient in mathematic logical thinking. The grades for self-regulated learning were fairly good, although no significant difference was found between the two groups. In addition, students' positive opinions of PBL did not correlate with their ability to employ logical thinking and self-regulation. Additionally, Monahan & Lee [19] found that utilizing a four-parameter logistic model as an estimation method for binary item parameters can be beneficial for generating more unbiased estimates when comparing methodologies that utilize item response models. Furthermore, based on item response theory, Al-Karamaneh [20] constructed a computerized adaptive test of logical intelligence for gifted students. As a result of the presence of a single dominant factor accounting for the majority of performance variance, the test met the assumptions of the three-way logistic model and demonstrated construct validity. Furthermore, the test demonstrated significant discriminant validity between gifted and normal students.

THE STUDY PROBLEM AND QUESTIONS

Using this test, ninth-grade students can enhance their mental abilities as well as their ability to develop mathematical skills to improve their performance in academics as well as their achievements in related fields, improving their academic performance. Additionally, it contributes to an improved academic performance and achievement in related areas of study. Mathematical education can enhance arithmetic skills and creative thinking by stimulating illogical and logical reasoning within the context of learning. Thus, a test that identifies these abilities is necessary for assessment among students. By analyzing student interactions with questions, item response theory can be applied to the analysis of student interactions in order to increase validity of the test as well as provide information on the level of difficulty and objectivity of the questions. By conducting this analysis, we gain a deeper understanding of students' interactions with the questions. It is also necessary to utilize numerous tools in order to conduct the study, in addition to its difficulty. It is essential to develop intelligent and rigorous assessment tools that meet students' needs and assess their true abilities via logical and mathematical intelligence tests based on item response theory.

An item response theory-based logical-mathematical intelligence test for ninth graders is examined for validity and effectiveness. Moreover, the research aims to identify the potential impact of test design on students' performance in mathematics topics, with the objective of examining how illogical and logical thinking influences the improvement of students' academic performance in the context of mathematical learning process. What is more, the purpose of this study was to answer the following questions:

- To what extent are the assumptions of item response theory fulfilled in the study data according to the three-parameter model?
- What are the implications of the validity and reliability of the logical-mathematical intelligence test when assessed using the three-parameter model?
- What are the parameters of the logical-mathematical intelligence test items (difficulty, discrimination, and guessing) estimated according to the three-parameter model?

OBJECTIVES OF THE STUDY

Based on item response theory, the study aimed to develop a test for ninth-grade students measuring logical-mathematical intelligence. Psychometric properties of this test are satisfactory, including acceptable validity and reliability, and item difficulty, discrimination, and guessing coefficients are acceptable.

THE IMPORTANCE OF STUDY

This study has a theoretical and scientific importance in the following ways: It may be considered of great importance in the context of improving the educational process and developing students' abilities in mathematics and illogical reasoning. By using item response theory, a test for logical-mathematical intelligence can be developed to meet the urgent need for smart and precise assessment tools focusing on a comprehensive understanding of the student's understanding of mathematical concepts and comprehension. As a result of this study, teachers and tutors will have a better understanding of students' thinking and be able to interact with them more effectively. More questions. In this way, educational performance is improved and students are provided with personalized learning opportunities. In addition, it is hoped that constructing a logical-mathematical intelligence test using item response theory will provide us with an opportunity to gain a better understanding of students' engagement with mathematics. By identifying which concepts students are adept at applying and which require reinforcement, it is possible to encourage both non-logical and logical thinking in the context of instruction.

This study represents a significant step towards improving assessment processes and guiding learning, thereby making an important contribution to the development of mathematical and intellectual achievement among ninth-grade students. It provides a test that measures logical-mathematical intelligence for school students, graded according to the three-parameter model. Additionally, this study offers insights into preparing intelligence tests using the three-parameter model, addressing the lack of local and Arab studies on constructing tests that measure logical-mathematical intelligence based on item response theory.

RESEARCH METHODS

A descriptive survey method was employed for the collection of data for this psychometric study. The logical-mathematical intelligence test was developed based on item response theory. The difficulty, discrimination, and guessing parameters of this test were described.

1. Study population and sample

The study population consisted of 1230 males and females from normal and gifted schools in the 1st semester of the 2023/2024 academic year. Additionally, 260 ninth-grade students who attended both normal and gifted schools were included in the study. They were selected by stratified random method with a percentage (21%) of the study population. Following is a table showing how the study sample members were distributed according to their gender and school type.

Table 1

Distribution of study sample members by gender and specialty

Variable	Level	N	Percentage
Gender	Male	207	79.6%
	Female	53	20.4%
	Total	260	100%
School	Gifted	110	42.3%
	Normal	150	57.7%
	Total	260	100%

2. limitations of study

The scope of this study was limited to regular schools and gifted schools and it was conducted in the 1st semester of the academic year (2023/2024). As a consequence, the results of this study can be generalized in light of the validity and reliability of the tools adopted, the psychometric properties of the tools adopted, and the logistic model employed.

3. Study Instrument

A thorough review of the theoretical literature on logical-mathematical intelligence was conducted using [6; 21] theory of multiple intelligences. To review the areas included in logical-mathematical intelligence, Armstrong's [22] book was referenced, and Abu Hamed [23] used the examples provided in his book to illustrate the points. Additionally, Naaloh [24]'s study was utilized to formulate logical thinking questions. Al-Trad [25] study was used to determine the type of paragraphs appropriate for gifted students. Identification of the areas of logical-mathematical intelligence that can be used to describe logical-mathematical intelligence, including: (problem-solving, logical thinking, discovering mathematical patterns and relationships, and using numbers) by reviewing the literature, understanding what logical-mathematical intelligence is and what it is measured for, and using tests to determine the level of logical-mathematical intelligence. Tests of intelligence used with gifted students, such as the Purdue Academic Rating Scales, PARS 5 are commonly used.

Following that, the initial form of the test was prepared by composing its items from areas of logical-mathematical intelligence, consisting of 46 multiple-choice items, each of which has four alternatives, but only one is correct for each item. The items were distributed across a wide range of logical-mathematical intelligence areas. An initial image of the test was presented to a group of arbitrators who are faculty members in Jordanian universities' departments of curriculum and teaching methods, educational measurement and evaluation, and to specialized arbitrators from the field to verify the apparent validity of the items as well as their relationship to their respective fields. As a result of the arbitration results, the items have been revised. The following changes were made: some misspellings or necessary reformulation, some ambiguous words were replaced, and some blurbs were rephrased to be more appealing. Verifying the clarity of the items and instructions, determining the time required to answer, and extracting the characteristics of the items (difficulty, discrimination) from the original form of the test. Table (2) presents the results of the initial experimentation conducted on (50) male and female students.

Table 2

Difficulty and discrimination coefficient values for the test items

No	Difficulty coefficient	Discrimination coefficient	No	Difficulty coefficient	Discrimination coefficient
1	0.64	0.33	24	0.24	0.46
2	0.26	0.10-	25	0.46	-0.06
3	0.62	0.25	26	0.56	0.54
4	0.58	0.30	27	0.60	0.21
5	0.50	0.23	28	0.42	0.43
6	0.18	0.22	29	0.28	-0.07
7	0.50	0.23	30	0.24	-0.02
8	0.20	0.21	31	0.22	0.27
9	0.34	0.26	32	0.52	0.41
10	0.32	0.27	33	0.26	0.48
11	0.70	0.37	34	0.42	0.55
12	0.28	0.43	35	0.30	0.25
13	0.36	0.22	36	0.42	0.52
14	0.16	0.22	37	0.26	0.56
15	0.52	0.23	38	0.20	0.38
16	0.58	0.26	39	0.16	0.28
17	0.18	0.25	40	0.28	0.77
18	0.22	0.28	41	0.16	0.26
19	0.32	0.21	42	0.26	0.31
20	0.20	0.25	43	0.22	0.52
21	0.34	0.21	44	0.10	0.37
22	0.48	0.38	45	0.46	-0.02
23	0.56	0.31	46	0.32	0.34
Mean=0.36			Mean=0.30		

It is shown in Table (2) that the difficulty coefficients for the items ranged between (0.10-0.70). Table (2) also indicates that the items with numbers (2, 25, 29, 30, 45) had negative discrimination, so these items were deleted, and the values ranged from 0.20 to 0.77 for the remaining items, resulting in a final number of 41 test items.

STUDY RESULTS

Findings related to the first question: To what extent are the assumptions of item response theory fulfilled in the study data according to the three-parameter model?

1. One-dimensional

The assumption of unidimensionality was verified using factor analysis with the principal components method (Principal Components Analysis) and orthogonal rotation of the axes (Varimax). An analysis of the data obtained from applying the 41-item test to 260 male and female students was conducted in this study. Kaiser [26] recommends a sample size that is at least 0.50 to determine the adequacy of the sample size. The Kaiser-Meyer-Olkin index (KMO-Index) yielded a value of 0.84 for the sample size adequacy index. The sample size adequacy index is considered acceptable if its value is between 0.50 and 0.70, good if between 0.70 and 0.80, and large if between 0.80 and 0.90. If the value exceeds 0.90, it is considered very large. The principal components, their number for the test, the percentage of explained variance, and the percentage of cumulative explained variance are shown in Table 3.

Table 3

Eigenvalues values and percentages of variance explained for the basic factors in the test

Factor	Eigenvalue	Explained variance %	Cumulative percentage of explained variance %
1	8.306	20.258	20.258
2	2.136	5.211	25.468
3	1.787	4.358	29.826
4	1.752	4.274	34.100
5	1.452	3.542	37.642
6	1.368	3.337	40.979
7	1.354	3.301	44.280
8	1.246	3.038	47.319
9	1.179	2.876	50.194
10	1.163	2.837	53.032
11	1.049	2.559	55.591
12	1.021	2.490	58.081

As indicated in Table (3), the latent root of the first factor is (8.306) and accounts for (20.258%) of the variance in the model; the ratio of the first factor's latent root value to the second factor's latent root value is (3.88), and as this ratio exceeds (2), this indicates that the model is one-dimensional and that a dominant factor exists, in accordance with the research conducted by [27]. A Scree Plot diagram depicts the relationship between the factors and the latent roots.

Based on the representation of the eigenvalues of the factors that constitute the test, it is observed that the slope of the curve shifts at the second factor, while the slope remains similar for the remaining factors. This implies there is a dominant factor from which one-dimensionality can be inferred [27].

2. Local independence

Because the assumption of unidimensionality has been met, it follows that the assumption of local independence has also been met, as suggested by [27].

3. Guessing

By observing the performance of subjects with low ability on the test, the low guessing index was verified.

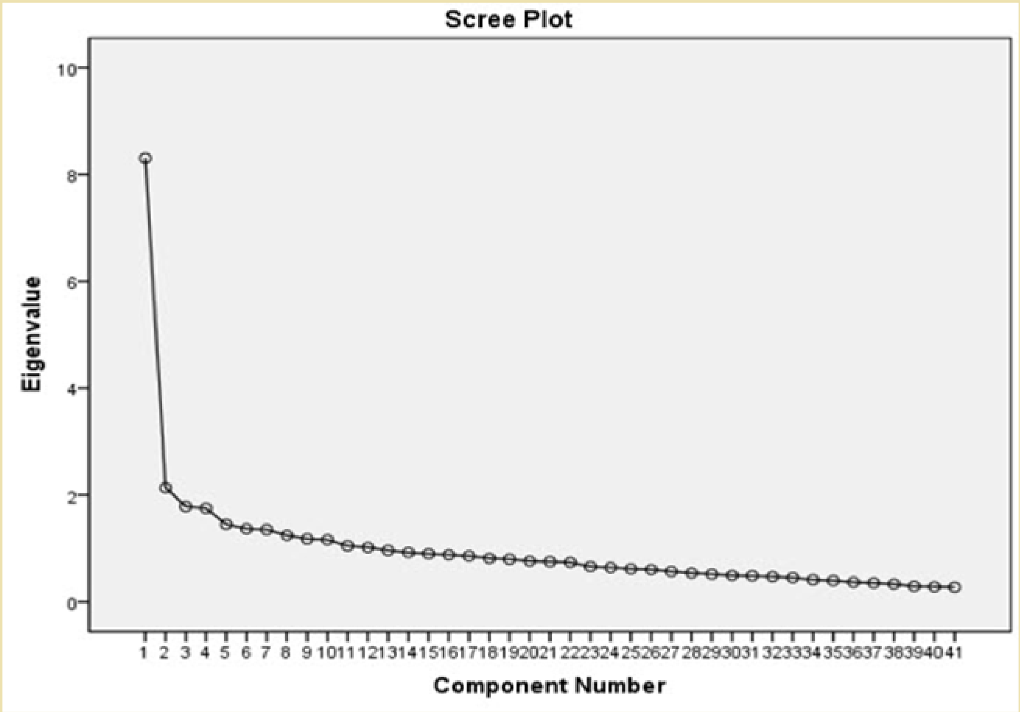

Figure 1 Graph of the eigenvalue of the basic factors that make up the test

4. Speedness

The percentage of students who were able to complete the test completely and the time required by students to complete it were used to verify this assumption. According to the report, the minimum time needed for the first student to complete the test was (55) minutes, while the maximum time required for the last student to complete the test was (62) minutes, indicating the students were given a total of 75 minutes to complete it. Additionally, it was noted that all students had completed all of the items. Therefore, it can be said that the student's inability to answer some of the test items is due to a lack of seriousness, focus, and indifference. Based on the percentage of subjects who completed (75%) of the test items and the number of students who completed (90%) of the test items, they have it, not the speed factor. As a result, the assumption that speed had no impact on the results was verified [28] through application.

Findings related to the second research question: What are the implications of the validity and reliability of the logical-mathematical intelligence test according to the three-parameter model?

Researchers used several methods to determine the validity and reliability of the test to answer this question:

5. Content validity

The validity of the test prepared in this study was verified through the procedures followed in preparing the test, which was demonstrated by presenting the test to a group of (10) arbitrators to determine the validity of the test content. In addition to amending the linguistic formulation and covering it, the arbitrators also provided suggestions and amendments. In terms of the domains, the test provided a good percentage of overall agreement among the arbitrators (85%) regarding the linguistic formulation, while the percentage of total agreement among the arbitrators (89%) regarding the items' coverage of the domains.

6. Discriminant validity

As part of the verification of the discriminant validity of the test, the arithmetic mean and standard deviation of the total score were determined, and a t-test was used to determine whether there was a significant difference in performance between gifted and ordinary students. Based on these results, it is evident that the test is capable of distinguishing gifted students from ordinary students. Table (4) illustrates how the t-test was used to analyze the differences between the arithmetic means of gifted and ordinary students' scores on the logical-mathematical intelligence test.

Table 4

T-test results for the differences between the arithmetic means of the scores of gifted and normal students on a logical-mathematical intelligence test

Test	Category	No	Mean	SD	df	t	Sig
logical- mathematical intelligence test	Gifted	110	28.30	6.01	258	21.64	0.00
	Normal	150	14.45	4.21			

In Table 4, it is apparent that there are statistically significant differences between the two averages, favoring the gifted students at a significance level of 0.05. The calculated t-value was 21.64, which is statistically significant at the significance level ($\alpha = 0.05$). This indicates the ability of the logical-mathematical intelligence test to distinguish between gifted students and ordinary students. This result is explained by the fact that there were a variety of items on the test that varied in difficulty according to the students' ability levels. There were easy items, medium items, and difficult items. The items of the scale were objective in nature and had high validity implications since they covered all logical intelligence areas. Moreover, the test has been presented to experienced and specialized individuals who have contributed significantly to refining the items to ensure that they are compatible with each of the fields in which they are based. The results confirm that the gifted student has higher mental, perceptual, and cognitive abilities than the average student.

7. Criterion-Related Validity

An analysis of the student's school grade in mathematics was performed in order to verify the validity of the test related to the test. The Pearson correlation coefficient was found between the grades obtained by students on logical-mathematical intelligence tests and their grades in mathematics in the second semester of the academic year. There was a correlation coefficient of (0.64) in 2022/2023. In order to explain this result, the researchers rely on the logical-mathematical field of knowledge, which is concerned with applying previous experiences to new and unfamiliar facts, persisting in looking for solutions, expressing assumptions, and justifying their methods throughout the long process. No doubt having the student has skills such as the ability to summarize information, the speed with which it can be assimilated and retrieved, his speed of learning, as well as academic excellence in all or most of the academic subjects. On the other hand, his possession of cognitive skills, such as analysis, evaluation, and reasoning, helps him benefit more from these skills than others.

8. Construct validity

As a means of verifying the validity of the construct, we conducted a factor analysis using Principal Component Analysis and rotation based on orthogonal axes (Varimax Rotation). The presence of one factor was verified through the procedures followed to verify the assumption of unidimensionality previously discussed in detail, which showed that there was one factor present. Prevalence explains the majority of variance in test performance. In Figure [1], the diagram of the latent roots Scree plots confirms this conclusion. The researchers explain this result by stating that the logical-mathematical-statistical processes need each other during the process of analyzing and understanding information in the process of solving problems, and they also require basic skills such as recognition, inference, understanding, and interpretation in order to solve problems effectively. The performance is based primarily on athletic ability, and this is one of the dominant factors behind it.

9. Test Reliability

Based on the three-parameter model, the empirical reliability coefficient for the test in its final form was extracted using the program (Bilog-MG-3.0), where the empirical reliability coefficient reached (0.852), which is a very high value. Additionally, the internal consistency reliability of the test was evaluated using the Cronbach alpha method using a statistical package known as (SPSS) and reached (0.87), which is a high value. Therefore, the test has a high degree of internal consistency (consistency of the internal structure), which is a sign of unidimensionality [29].

Findings related to the third question: *What are the parameters of the logical-mathematical intelligence test items (difficulty, discrimination, guessing) estimated according to the three-parameter model for the test items matching the model?*

Following the deletion of items and individuals that did not fulfill the requirements of the tripartite model, the characteristics of each itemof the test were analyzed by using the software (Bilog-MG-3.0). The analysis resulted in all individuals conforming to the model. The researchers explain this to the students' seriousness and their tendency to respond to the items in a concentrated manner. The analysis also revealed that items 22, 25, and 34 did not match the model based on the Chi-Square Statistics value at the significance level (α = 0.05), where their probability values were less than 0.05. Consequently, the final form of the test consisted of 38 items. In Table 5, the parameters for difficulty, discrimination, guessing, and standard error have been determined for the items of the logical-mathematical intelligence test using a three-parameter model.

Table 5

Values of: difficulty, discrimination, guessing, and standard error of the logical-mathematical intelligence test items according to the three-parameter model

Item No	Difficulty Parameter(b)	The standard error for (b)	Discriminate (a)	Standard error(a)	Guessing parameter (c)	Guessing standard error
1	-0.980	0.458	0.732	0.160	0.254	0.097
2	0.345-	0.323	1.155	0.267	0.271	0.097
3	0.609-	0.389	0.827	0.172	0.239	0.092
4	0.328-	0.208	1.632	0.320	0.203	0.079
5	2.635	0.711	1.538	0.850	0.196	0.032
6	0.351-	0.240	1.349	0.246	0.205	0.080
7	0.899	0.118	2.479	0.656	0.123	0.034
8	0.015	0.268	1.254	0.270	0.220	0.082
9	0.596	0.287	1.335	0.403	0.283	0.081
10	-0.376	0.216	1.899	0.454	0.255	0.090
11	0.917	0.148	2.359	0.894	0.235	0.047
12	0.532	0.234	1.489	0.387	0.227	0.071
13	1.006	0.175	1.662	0.465	0.155	0.048
14	0.906	0.442	0.836	0.245	0.273	0.087
15	0.127-	0.278	1.394	0.338	0.269	0.092
16	1.906	0.332	1.491	0.575	0.128	0.036
17	0.317	0.165	1.669	0.278	0.131	0.052
18	2.885	0.690	0.959	0.429	0.342	0.050
19	0.507	0.147	2.025	0.440	0.137	0.048
20	1.650	0.309	1.418	0.597	0.273	0.051
21	0.115-	0.185	2.167	0.460	0.221	0.075
22	0.421	0.142	2.493	0.652	0.173	0.052
23	0.145-	0.245	1.530	0.350	0.240	0.086
24	0.447	0.152	2.705	0.753	0.238	0.053
25	0.945	0.249	1.282	0.366	0.206	0.066
26	0.036-	0.213	1.833	0.402	0.245	0.079

27	1.409	0.229	1.484	0.511	0.212	0.050
28	0.573	0.129	2.944	1.062	0.200	0.049
29	0.194	0.152	2.538	0.598	0.203	0.059
30	1.558	0.256	2.187	1.218	0.337	0.042
31	1.209	0.157	2.498	0.985	0.272	0.041
32	0.804	0.103	4.283	1.676	0.198	0.043
33	1.164	0.300	1.110	0.345	0.225	0.068
34	0.773	0.135	2.468	0.695	0.184	0.042
35	0.410	0.459	1.932	0.459	0.164	0.057
36	2.682	0.758	1.086	0.498	0.256	0.046
37	1.050	0.162	1.897	0.591	0.176	0.046
.38	1.176	0.305	1.029	0.294	0.193	0.066

Clearly, from Table (5), the difficulty parameter ranges from (0.98) to (2.885) with an average of (0.689), whereas the discrimination parameter ranges from (0.732) to (4.283) with an average of (1.762). In this study, it is evident that the difficulty range of the items was large, and the discrimination coefficients were very high. Estimation parameters ranged from (0.123 to 0.342) with an average of (0.220). The grade distribution curve on the trait continuum appears to be relatively flat, as indicated by [30]. This implies that a group of items has a higher level of discrimination and a wider range of difficulty than the difficulty parameter. Therefore, these estimates of item parameters can be regarded as acceptable by psychological and educational measurement standards.

Researchers may be able to explain this result regarding the difficulty parameter values by stating that the items covered a wide range of the trait continuum, ranging from easy to difficult. In addition, the researchers have explained the range of difficulty parameter values to the homogeneity of the test items, since the test is designed to measure only one trait, and that the discrimination coefficients are high. It indicates the ability of the test items to distinguish between individuals who possess a different amount of the trait, and the higher the discrimination coefficient, the more likely that the item will be able to categorize and grade the subjects based on their abilities. Also, the high difficulty parameter makes answering any test item require a high level of ability of the examinee, in addition to the low values of the estimation parameter for the items and the low standard errors in estimating the parameters of the items estimated according to the modern theory of measurement. As a result, test items are able to distinguish between two or more categories of subjects based on certain foundations related to the level of ability of these subjects. As for the estimation coefficients, they are low, which indicates that individuals of low ability have a low percentage of correct answers to difficult items.

DISCUSSION OF THE RESULTS

According to the three-parameter model, the study results of the first question indicated that the assumptions of item response theory were fulfilled in the study data for constructing a logical-mathematical intelligence test for ninth-grade students [30; 31]. Additionally, the study results demonstrated that the test was valid and reliable. Based on Embretson and Reise [32], the grade distribution curve is relatively flat on the trait continuum and this indicates that a group of items has high discrimination and a wider range than the difficulty parameter. The results of this study can be attributed to the soundness and accuracy of the practical procedures followed in the creation of the study tool, as well as to the selection of the study sample and the correct methodology. Further, logical-mathematical thinking is particularly important, especially when students are required to think logically and draw new conclusions based on evidence, which is consistent with the results of Prastika's study [33]. According to the results of this study, students with logical-mathematical intelligence were capable of gathering evidence, solving problems, designing distinctive models, and identifying mathematical relationships.

As a final note, the study tool is being applied in its final form after verifying the assumptions of the item response theory [34]. It is therefore possible to conclude that the estimates of item parameters in this study are acceptable within the standards of psychological and educational measurement. Considering the difficulty parameter values, the researchers may have explained this result by stating that the items covered a wide range of trait continuums, from easy items to difficult items. According to the researchers, the range of difficulty parameter values is due to the homogeneity of the test items, since only one trait is measured, and the discrimination coefficients are very high [35]. It indicates the ability of the test items to distinguish between individuals who possess a different amount of the trait, as the higher its discrimination coefficient, the more likely it is to classify the subjects and grade them according to their abilities [36]. Additionally, the high difficulty parameter requires high abilities from the examinee in order to answer any test item, in addition to the low estimation parameter values for the items and the low standard errors in estimating the parameters of the items based on modern measurement theory [34]. As a result, the test items can be used to distinguish between two or more categories of subjects classified according to certain foundations relating to their ability level. As for the estimation coefficients, they indicate a low percentage of correct answers to difficult items by individuals with low abilities.

These results also aligned with those reported by Alnasraween [15] which indicated that the items were discriminating and covered a wide range of difficulty levels, according to appropriate discriminating indicators. In order to evaluate the validity and reliability of the test, a variety of methodologies were employed, including content validity and internal consistency [34]. In accordance with the study's findings, the majority of test items met the assumptions of the two-parameter logistic model for the private sector [35]. An investigation conducted by Al-Abdallat [37] examined the effect of an instructional program based on the Multiple Intelligences Theory (MIT) on the English achievement of ninth grade students. A MIT-based program significantly improved English skills, with the experimental group scoring higher (55.20) than the control group (46.45).

The results of this study support the current idea that educational programs designed to cater to specific intelligences, such as logical-mathematical intelligence, are more likely to produce positive outcomes for students. According to both studies, integrating MIT or focusing on specific intelligences may lead to more effective educational practices and improved performance across subject areas. Similarly, Nurhidayati et al. [38] study's aligns with this study's findings in reinforcing the importance of logical-mathematical intelligence in enhancing problem-solving abilities and critical thinking across various academic tasks. Additionally, Lin [39] and Yao et al. [40] indicate that fostering intellectual growth through targeted educational methods improves problem-solving abilities and learning outcomes, reinforcing the conclusion of this study regarding the effectiveness of tailoring instructional methods to students' cognitive strengths.

CONCLUSION

One of the most important theories in educational psychology and measurement science is item response theory. An individual's behavior on a test and their response to the tasks presented are examined in this theory, which focuses on understanding his or her behavior. According to the theory, responding to an item can provide valuable information about individual abilities and skills. Paragraph response theory provides an opportunity to deeply understand an individual's thinking and knowledge styles as well as to assess the level of knowledge and skills the individual has in a given field. In order to ensure the validity and reliability of tests and their measurements, item response theory is crucial to the construction of scales and tests. In addition, IRT enables researchers and measurement professionals to analyze test results more deeply, thereby enabling them to make better decisions based on the available data. In this study, item response theory was employed in order to construct a logical-mathematical intelligence test for ninth grade students. Based on the results of this study analysis, it was concluded that this scale possesses appropriate psychometric properties that can be used by researchers and those interested. In addition, IRT enables researchers and measurement professionals to analyze test results more deeply, thereby enabling them to make better decisions based on the available data. In this study, item response theory was employed in order to construct a logical-mathematical intelligence test for ninth grade students. Based on the results of this study analysis, it was concluded that this scale possesses appropriate psychometric properties that can be used by researchers and those interested. In order to validate the test properties, the study recommends utilizing the study instrument, a logical-mathematical intelligence test for school students, utilizing IRT to build tests on various types of intelligence and academic subjects, and verifying the test properties using two parameter models and one parameter models of IRT.

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