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Psychometric properties of an instrument to measure the algebra proficiency of student teachers

Propiedades psicométricas de un instrumento para medir el dominio del álgebra de estudiantes en formación docente

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ABSTRACT

This research is a continuation of the instrumental study that consisted of designing an instrument to measure the algebra proficiency (IMDA) of Mexican students in teacher training. The first stage included application of the Delphi method, expert judgment, content validity test using the Hernandez-Nieto coefficient and piloting with 79 undergraduate students in pedagogy, which resulted in a KR-20 alpha reliability coefficient of 0.89 and excellent content validity. The present study was carried out with the objective of finding out if the IMDA is prepared for a larger scale project and was verified through two ways: a) Determination of the psychometric properties of reliability and content validity; the first through the KR-20 alpha coefficient and the second through item quality; b) Measurement of variability through the regression model. The sample consisted of 333 undergraduate students in public institutions of higher education in the state of Durango, Mexico. The results indicated the following: a) Reliability of the KR-20 alpha with a value of 0.84 and acceptable values in the statistical mean of the difficulty index (MIdif=0.59) and discrimination index (MIdisc=0.31); b) The R-squared coefficient of determination indicated that the proportion of variability of the dependent variable is significantly explained by all the independent variables in the regression model. It is concluded that the IMDA is reliable and has validity to generalize results in measuring the algebra proficiency of students in teacher training.

Keywords:
formação de professores, Instrumentos de avaliação, Psicometria.

RESUMO

Esta investigação é uma continuação do estudo instrumental que consistiu na conceção de um instrumento para medir a proficiência em álgebra (IMDA) dos estudantes mexicanos em formação de professores. A primeira fase incluiu a aplicação do método Delphi, a opinião de peritos, o teste de validade de conteúdo utilizando o coeficiente de Hernandez-

Nieto e a pilotagem com 79 estudantes de licenciatura, o que resultou num coeficiente de fiabilidade alfa KR-20 de 0,89 e numa excelente validade de conteúdo. O presente estudo foi realizado com o objetivo de averiguar se o IMDA está preparado para um projeto de maior escala e foi verificado através de duas formas: a) Determinação das propriedades psicométricas de fiabilidade e validade de conteúdo, a primeira através do coeficiente alfa KR-20 e a segunda através da qualidade dos itens; b) Medição da variabilidade através do modelo de regressão. A amostra foi constituída por 333 estudantes de licenciatura de instituições públicas de ensino superior do estado de Durango, México. Os resultados indicaram o seguinte: a) Fiabilidade do alfa KR-20 com um valor de 0,84 e valores aceitáveis na média estatística do índice de dificuldade (MIdif=0,59) e do índice de discriminação (MIdisc=0,31); b) O coeficiente de determinação R-quadrado indica que a proporção de variabilidade da variável dependente é significativamente explicada por todas as variáveis independentes no modelo de regressão. Conclui-se que o IMDA é fiável e tem validade para generalizar os seus resultados.

ABSTRACT

Palabras clave:
formación docente, Instrumentos de evaluación, Psicometría.

Esta investigación es continuidad al estudio de carácter instrumental que consistió en diseñar un instrumento para medir el dominio del álgebra (IMDA) de estudiantes mexicanos en formación docente. La primera etapa incluyó aplicación del método Delphi, jueceo de expertos, prueba de validez de contenido mediante el coeficiente de Hernández-Nieto y piloteo con 79 estudiantes de licenciatura en pedagogía, el resultado arrojó un coeficiente de fiabilidad del alfa KR-20 de 0.89 y excelente validez de contenido. El presente estudio se realizó con el objetivo de conocer si el IMDA está preparado para un proyecto de mayor escala y se verificó mediante dos vías: a) Determinación de las propiedades psicométricas de fiabilidad y validez de contenido; la primera mediante el coeficiente alfa KR-20 y la segunda a través de la calidad del ítem; b) Medida de variabilidad a través del modelo de regresión. La muestra estuvo constituida por 333 estudiantes de licenciatura de instituciones públicas de educación superior del estado de Durango, México. Los resultados indicaron lo siguiente: a) Fiabilidad del alfa KR-20 con un valor de 0.84 y valores aceptables en la media estadística del índice de dificultad *(MIdif=0.59)* e índice de discriminación *(MIdisc=0.31);* b) El coeficiente de determinación R-cuadrado indicó que la proporción de variabilidad de la variable dependiente es explicada de manera significativa por todas las variables independientes del modelo de regresión. Se concluye que el IMDA es fiable y tiene validez para generalizar sus resultados.

Introduction

Mathematical thinking involves the development of mathematical activities related to counting, measurement, representation, inference and modeling Rodríguez-Álvarez and Duran-Llaro (2023), the result of these activities has an impact on the development of the individual, so it is important that future teachers develop knowledge and ability to analyze and propose practices that favor the learning of mathematics and the development of mathematical thinking in students, aspects where the use of algebra is fundamental.

In general, mathematical practice refers to mathematical creation and/or production and consists of promoting the knowledge of formal mathematical language and its application, since according to Bueno and Vivanco (2023), formal languages are important tools for inference and discovery, fundamental aspects that can allow mathematical demonstrations to be carried out in teaching practice at any educational level.

The process for the development of mathematical thinking and the application of mathematics starts from preschool education, where the use of mathematical language is relevant, even if it is not developed in a formal way, however, the learning that is achieved will be fundamental for primary education to address the use and understanding of mathematical symbols correctly, this idea is shared by Alsina (2015), who argues that at this educational level mathematical demonstrations cannot be performed but points out the importance of performing simple proofs

The student in the process of teacher training should have mastery of early algebra as a means to favor algebraic thinking in the first grades of elementary education (Pinto et al., 2023), the fact of recognizing this thinking as a way of thinking and operating with objects, relations and mathematical structures, facilitates the student to understand and find meaning in mathematics. The practice of early algebra is facilitated if it is promoted through real situations, in which there is room for reasoning and argumentation in a way that leads them to understand mathematical properties, the identification of patterns and the representation of relationships, aspects that allow children to make generalizations (Pincheira and Alsina, 2021).

The algebraic content in the subject of mathematics in secondary education corresponds to the thematic axis number, algebra and variation, specifically in the academic content of addition and subtraction of algebraic expressions; this academic content begins to be handled in the first year of secondary school and has transcendence in the following school cycles.

The teaching of algebra in secondary education is fundamental for the academic and personal development of students; this discipline provides essential tools to solve mathematical problems, fosters critical thinking and logic, skills necessary in everyday life and in their training process (Aguirre and Cerati, 2020). The mastery of algebra is a tool that serves students to improve their academic performance and a basis for further studies in science, technology, engineering and mathematics, therefore, understanding the importance of teaching algebra at this stage is important to form competent and analytical citizens.

In secondary education it is common to perform formal and non-formal mathematical demonstrations, these include processes of identification and analysis of errors in the use of algebra, especially those related to the acquisition of algebraic language and the transition from arithmetic to algebra (Avila, 2016).

At the upper secondary education level, formal demonstrations are generalized and this educational space is a crucial point for the development of algebra because to a

greater or lesser extent, this area of the exact sciences is relevant and has competence in the professional world (Márquez, 2019), since it is undeniable that there is a close correlation between technological development in a society and the involvement of mathematics.

It is at this educational level where mathematics acquires greater preponderance (Universidad Europea, 2023), because it is there where the processes for entrance selection, as well as those for selection for higher education studies, become formal, due to the fact that this subject is part of the curricula in a wide variety of undergraduate careers.

The study of mathematics in higher education institutions training teachers is relevant, because students must acquire tools to promote the development of their mathematical ability and facilitate problem solving, in this same sense, Aké (2019), argues that teacher training should incorporate the study of situations that allow rethinking arithmetic notations and operations in a different way than the typical; that is, cultivate a new way of arithmetic thinking in which the basic notions of algebra can be built.

The enrollment of teacher training institutions is composed of students who completed their high school studies in technical or humanistic schools, regardless of the type and modality of secondary education received. These students should have a good command of algebra; however, in practice it has been shown that a considerable number of these students have problems with knowledge and application in this area of mathematics (Craveri, 2009).

To address this problem, it is convenient to carry out a diagnostic evaluation of students in order to know their level of mastery of algebra. This implies carrying out systematic and reflective processes to obtain quantitative and qualitative information on student learning, a situation that can be achieved through the application of various instruments, among them, exams in their different types and modalities.

Regardless of the educational level, learning algebra is important for the personal development of schoolchildren, because the appropriation of the necessary knowledge in the field of mathematics is fundamental for the student to achieve an intellectual and integral development that is reflected in their daily academic and daily life.

In this regard, it is worth mentioning that basic education teachers are the first promoters of learning and application of mathematical content, therefore, it is important that in their training process they become professional in this area of knowledge since teacher training institutions recognize the need and importance of strengthening the development of mathematics to help future teachers acquire skills that will allow them to guide their students in learning this discipline (Pérez, 2022).

In the teaching-learning process in the various disciplines or training fields, the teacher promotes evaluation activities, either to promote the improvement of learning or for accreditation purposes, in this regard, it is recognized that students present deficiencies that originate in their teacher training process; for this reason, it is convenient to address the suggestion of Pires (2024), who expresses the need for educational institutions and policy makers to prioritize the offer of specific courses and workshops to improve the evaluation skills of teachers.

In general, the teacher emphasizes an evaluation process for the achievement of learning, this implies carrying out systematic and reflective processes of obtaining quantitative and qualitative information about student learning (Hamodi et al., 2015), an educational action that can be achieved through the application of various instruments, among them, exams in their different types and modalities.

The information recovered through the previously mentioned evaluation instruments should be analyzed with methodological rigor to identify strengths and

barriers that students face at the beginning, during and at the end of an educational process, in order to guide their improvement. In this sense, the authors Sepúlveda-Obreque et al. (2017), state the need to promote the improvement and training of teachers on issues related to the assessment of learning and performance, as well as the application of instruments and their subsequent analysis to assess mastery in the field of mathematics and development of mathematical thinking in students and teachers.

In accordance with the above appreciations, this research work is the continuity of a study that, in the first part, consisted of designing an Instrument to Measure Algebra Proficiency [IMDA] (Ochoa and Rivera, 2024) and was aimed at Mexican students in teacher training. The IMDA construction process went through the stages of the Delphi method and expert judgment, content validity testing by means of the Hernandez-Nieto coefficient (Hernandez-Nieto, 2002), and a pilot test with 79 undergraduate students in pedagogy, a process that registered a reliability coefficient of Kuder Richardson's alpha 20 with a value of 0.89.

The second part of the study that occupies the present investigation, was carried out with the general objective of knowing if the IMDA is prepared for a larger scale project, this situation was verified through two ways: a) Determination of the psychometric properties of reliability and content validity, the first through the Kuder-Richarson alpha 20 coefficient and the second through the quality of the item and; b) Measurement of variability through the application of the Multiple Linear Regression method.

Method

This research was conducted based on the quantitative methodological approach with an instrumental design. According to Montero and León (2007), the study is considered instrumental in nature, given that the study consisted of determining the psychometric properties of the IMDA.

Sample and Participants

The total sample consisted of 333 students in teacher training who were currently pursuing their undergraduate studies in various public institutions of higher education in the state of Durango, Mexico. The selection of participants was non-probabilistic (Otzen, and Manterola, 2017). The sample size was determined according to the criteria set forth by Roco et al. (2021), which consists of having a minimum of five and a maximum of 10 subjects per item, an ideal number for the application of an improved instrument.

Instrument and Validation Process

In the first part of the study, the design of the IMDA was composed of 30 items distributed in five dimensions (García et al. 2019), with the following structure: a) Dimension 1; Moving from Arithmetic to Algebra (PAA), with six items; b) Dimension 2; Reversibility of Thought (RP), with six items; c) Dimension 3; Identifying Patterns (IP), with six items; d) Dimension 4; Generalization of Knowledge (GC), with six items and; e) Dimension 5; Abstraction and Reflection in Mathematical Processes (ARPM), with six items. IMDA are located in the Annexes section (see Annex 1).

Data Analysis

The data processed in the research process were organized and classified with the use of the Excel spreadsheet and analyzed with the support of the SPSS statistical program. The tests performed with the results of the IMDA application were the following: measures of central tendency, reliability test, item quality test and variability test by means of the multiple linear regression model.

Measures of Central Tendency

The measures of central tendency used in the analysis were the score obtained in each dimension of the IMDA and the total score.

Reliability Test

The reliability of the instrument was calculated using the Kuder-Richardson coefficient, specifically the KR20 formula, because it is a method used to evaluate the internal consistency of a measure based on dichotomous data. The calculation to determine this psychometric property is a formula that considers the variance of the item scores and is the dichotomous equivalent of the alpha coefficient (López et al., 2019).

Item Quality Test

The quality of an item was measured based on the value of its difficulty index and discrimination index, these statistics are closely related, however, it is important to note the special effect of the discrimination index, because according to the statement of Hurtado (2018), the determination of the norm value of discrimination influences the interpretation of the quality of the performance test. To determine the value of the item difficulty and discrimination index, the method used by Backhoff and Rosas (2000) was used; Table 1 shows the range of values of the difficulty and discrimination index to interpret the quality of the item.

Table 1

Classification and interpretation of difficulty and discrimination indexes

Difficulty index		***Discrimination index***		***Recommendation***
Ranking of the item	Index value	Ranking of the item	Index value	
Easy	0,91-1	Lousy	< 0,01	Discard
Relatively easy	0,81-0,90	Poor	0 a 0,19	Discard or revise
Adequate difficulty	0,51-0,80	Regular	0,20 a 0,29	Check
Relatively difficult	0,40-0,50	Good	0,30 a 0,39	Possibility to improve
Difficult	0-0,39	Excellent	0,40 a 1	Preserve

IMDA Variability Measure

The regression model was used to determine the variability of the score of the dependent variable with respect to the value of its statistical mean, and to evaluate whether this variability is significantly explained by the independent variables that intervened in the model

The regression model outputs as the main evaluator of variability the coefficient of determination R^2 (Rodríguez and Salmerón, 2018). The variables that intervened in the process were the total score and the score per dimension obtained by the participants in the response to the IMDA, for the purpose of the operational work in the SPSS statistical program, these were coded as follows:

1) Score obtained by the participants in the response to the IMDA (P_{IMDA}). According to the regression model, this variable corresponds to the dependent variable or response variable.
2) The scores obtained by the participants in each of the IMDA dimensions were: a) *Passage from Arithmetic to Algebra* (P_{PAA}); b) *Thought Reversibility* Score (P_{RP}); c) *Pattern Identification* Score (P_{IP}); d) *Generalization of Knowledge* Score (P_{GC}) and; e) *Abstraction and Reflection in Mathematical Processes* Score (P_{ARPM}). According to the regression model, these variables correspond to the independent variables or predictor variables.

To determine the dependence and relationship between these variables, the regression analysis was performed based on the following regression model.

$$y = \beta_o + \beta_1 x_1 + \beta_2 x_2 + \cdots + \beta_i x_i$$

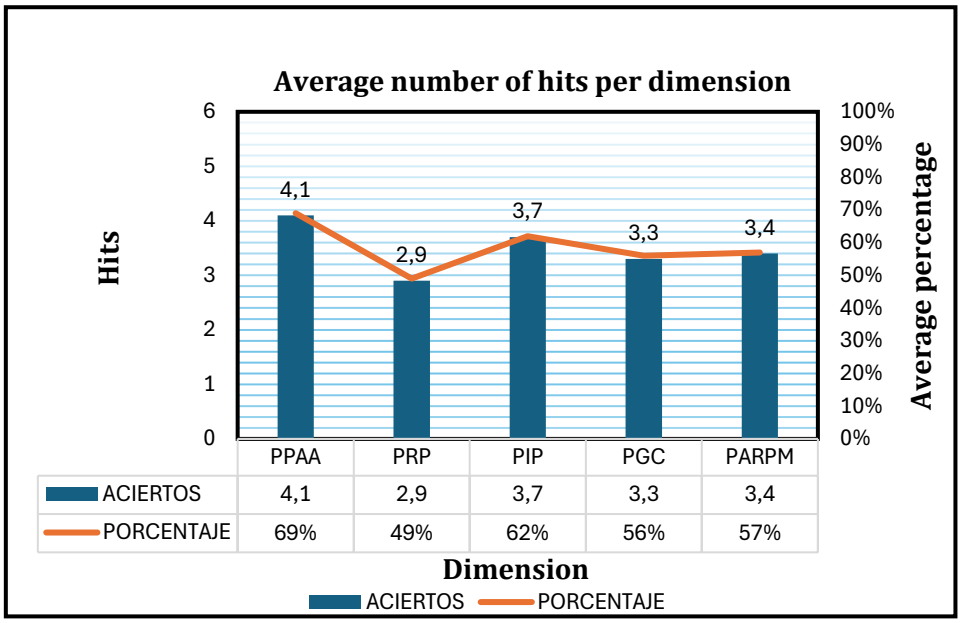
Results

Measures of Central Tendency

The graph in Figure 1 shows the value of the statistical mean of hits recorded in each dimension of the IMDA, here it can be seen that there is a balanced score between dimensions, which is confirmed with reference to the value of the mean of the statistical means of hits *($M_{DIMENSIONS}=3.5$)*

Figure 1

Average number of hits by IMDA dimension



The score obtained by the participants in the response to the IMDA *(P_{IMDA})* can be found in the annexes section (see annex 1), in these data is the value of the statistic of the mean of the P_{IMDA} score (M_{IMDA}=17 hits), this value indicates that, on average, the 333 students obtained 17 hits in the response to the 30 items of the IMDA.

Reliability measurement

The result of the reliability measure is shown in Table 2, the calculation was made through the Kuder-Richardson alpha 20 formula, according to Duran and Abad (2021), the value of the coefficient *(KR-20=.846)* is good, since the authors consider it acceptable when it is between .75 and .90.

Table 2

Reliability test result

Reliability statistics	
Alpha 20 of Kuder-Richardson	N of elements
.846	30

Content Validity of IMDA

Item Quality

Table 3 shows the value of the difficulty index and discrimination index of each item, where it is observed that the 30 items are considered of acceptable quality since they were located within the pre-established range of quality, likewise, it can be seen that the value of the statistical mean of the difficulty index (M_{Idif} = .59) is recognized with an

adequate difficulty and the value of the statistical mean of the discrimination index (M_{Idisc} = .31) is recognized as *good*, both with the possibility of being improved.

Table 3
Difficulty and discrimination indexes

item	Idif	Idisc	item	Idif	Idisc	item	Idif	Idisc
1	0.49	0.31	11	0.48	0.33	21	0.52	0.35
2	0.68	0.38	12	0.52	0.38	22	0.61	0.36
3	0.77	0.26	13	0.59	0.38	23	0.50	0.24
4	0.70	0.27	14	0.43	0.40	24	0.59	0.30
5	0.77	0.27	15	0.63	0.34	25	0.64	0.33
6	0.72	0.34	16	0.70	0.26	26	0.61	0.31
7	0.44	0.37	17	0.60	0.22	27	0.47	0.43
8	0.63	0.34	18	0.78	0.29	28	0.41	0.21
9	0.49	0.36	19	0.66	0.20	29	0.59	0.21
10	0.38	0.35	20	0.47	0.22	30	0.69	0.31
							M_{Idif}=.59	M_{Idisc}=.31

Variability Test

Table 4 shows the summary of the regression model; the value of the R-squared determination coefficient of model 1 indicates that the variability of the independent variable P_{IP} explains 64.2% of the variability of the dependent variable P_{IMDA}. In the subsequent models, the value of the R-squared coefficient of determination increases with the progressive incorporation of the independent variables P_{PAA}, P_{ARPM}, P_{GC}, and P_{RP}, until it indicates that the explained variability provided by the scores covers practically 100% of the variability of the P_{IMDA} score. The explanation of variability offered by all the variables is important, as shown by the value of the Fisher-Snedecor (F) change statistic, whose value in each model is acceptable and with a significant "p" value.

Table 4
Summary of the model

Summary of the model

Model	R	R square	Adjusted R-squared	Standard error of the estimate	gl	F	Sig.
1	,801[a]	,642	,641	3,695	331	593,499	,000
2	,908[b]	,824	,823	2,594	330	773,031	,000
3	,951[c]	,905	,904	1,914	329	1038,982	,000
4	,977[d]	,955	,955	1,315	328	1742,881	,000
5	1,000[e]	1,000	1,000	,000		.	.

a. Predictors: (Constant), P_{IP}
b. Predictors: (Constant), P_{IP}, P_{PAA}
c. Predictors: (Constant), P_{IP}, P_{PAA}, P_{ARPM}
d. Predictors: (Constant), P_{IP}, P_{PAA}, P_{ARPM}, P_{GC}
e. Predictors: (Constant), P_{IP}, P_{PAA}, P_{ARPM}, P_{GC}, P_{RP}

A complementary result to the R-squared coefficient of determination test is the diagnosis of collinearity Salmerón and Rodríguez (2017). Table 5 shows that, in each regression model, the collinearity statistic *Tolerance* yielded values close to "1"; these

values are indicative of low collinearity between the independent variables, a result that reaffirms its effect on the regression model.

Table 5
Collinearity statistics

Excluded variables[a]

Model		In beta	t	Sig.	Partial correlation	Collinearity statistics Tolerance
1	P_{PAA}	,483[b]	18,485	,000	,713	,781
	P_{RP}	,502[b]	17,176	,000	,687	,671
	P_{GC}	,400[b]	12,750	,000	,574	,738
	P_{ARPM}	,466[b]	16,501	,000	,672	,747
2	P_{RP}	,350[c]	14,631	,000	,628	,565
	P_{GC}	,316[c]	14,918	,000	,635	,710
	P_{ARPM}	,345[c]	16,648	,000	,676	,674
3	P_{RP}	,299[d]	18,787	,000	,720	,552
	P_{GC}	,270[d]	19,207	,000	,728	,693
4	P_{RP}	,286[e]	.	.	1,000	,551

Another indicator of absence of collinearity between the scores of the independent variables is the existence of moderate correlation and absence of high correlation between pairs, Table 8 shows that the correlation values between pairs oscillate in the range of values (.386 < r < .574), i.e., the condition that demonstrates absence of collinearity established by Goode-Romero (2019) is met, and consists of excluding pairs of variables that indicate a correlation coefficient (r > 0.6).

Table 6
Correlation between pairs of variables

Correlations

		P_{PAA}	P_{RP}	P_{IP}	P_{GC}	P_{ARPM}
P_{PAA}	Pearson correlation	1	,556**	,468**	,386**	,473**
	Sig. (bilateral)		,000	,000	,000	,000
	N	333	333	333	333	333
P_{RP}	Pearson correlation	,556**	1	,574**	,392**	,471**
	Sig. (bilateral)	,000		,000	,000	,000
	N	333	333	333	333	333
P_{IP}	Pearson correlation	,468**	,574**	1	,512**	,503**
	Sig. (bilateral)	,000	,000		,000	,000
	N	333	333	333	333	333
P_{GC}	Pearson correlation	,386**	,392**	,512**	1	,411**
	Sig. (bilateral)	,000	,000	,000		,000
	N	333	333	333	333	333
P_{ARPM}	Pearson correlation	,473**	,471**	,503**	,411**	1
	Sig. (bilateral)	,000	,000	,000	,000	
	N	333	333	333	333	333

Discussion and Conclusions

Regarding the result of the application of the IMDA, the measures of central tendency indicated that there is a balance between the value of the statistical mean of the five dimensions the statistical mean value of the mean scores of the five dimensions, a

situation that reflects homogeneity in the response to the IMDA and is indicative of an adequate measure of the *algebra mastery construct*.

With attention to the objective of this research, the IMDA was applied to 333 students in teacher training and it was found that the reliability statistic continues to indicate a fairly acceptable value *(KR-20=.84)*, only five hundredths below the value obtained in the pilot test *(KR-20=.89)*; this result confirms that there is a good internal consistency between items and stability over time of the IMDA.

In relation to the item quality measure, it was found that each of the 30 items registered acceptable values in their difficulty and discrimination indexes, since they were located within the range established to be considered of good quality; the same occurred with the set of items that registered acceptable values in the statistical mean of their difficulty index ($M_{dif} = .59$) and in the statistical mean of their discrimination index ($M_{dif} = .31$); these results indicate that, in general, the IMDA items are moderately simple and that they differentiate between those who have and those who do not have a good command of algebra.

The variability test performed through the regression model indicated that the variability of the dependent variable was significantly explained by each of the independent variables up to 100%. This result was supported by the value of the R-squared coefficient of determination recorded in each model, which is shown in the summary of the regression model. These results indicate that the observed variability of the IMDA is systematic or random, a characteristic that contributes to obtaining reliable and consistent information, for the particular case, on the measure of algebra proficiency of students in teacher training.

A result that complements the IMDA variability measure is the *Tolerance* collinearity diagnosis, which yielded values close to "1." The value of this statistic indicates low collinearity among the independent variables in the regression model. This means that the variables are not strongly correlated with each other and that each independent variable provides unique information on the dependent variable; consequently, the regression model is more stable and the coefficients are more reliable, characteristics that improve the accuracy of the IMDA estimates. In support of the result of the collinearity test, a correlation test was performed between pairs of independent variables and a moderate positive correlation was found in each of them.

Once the IMDA was subjected to rigorous studies with a larger number of participants, it was confirmed that it has psychometric properties of reliability and content validity, in addition, the results of the variability test indicated that the IMDA also has the capacity to detect significant differences between individuals or groups.

These psychometric properties and characteristics exhibited by the IMDA increase its robustness and generalization of the results, guaranteeing that the instrument is accurate and useful to be applied in teacher training populations where students with a wide diversity in the mastery of algebra converge, since, at the undergraduate level, students who studied their baccalaureate in technical and humanistic schools attend.

With the application of the IMDA, we expect to obtain a diagnostic evaluation that will allow us to undertake actions focused on strengthening the development of mathematical thinking of students in teacher training, so that, when they are integrated into their educational practice, they will have more and better tools to facilitate the learning and educational practice of their students in this area of knowledge.

With the purpose of extending the usefulness of the IMDA, it remains to be tested in populations of different educational levels, since the structure and level of complexity of the items were carefully designed. On the other hand, there is also the concern of testing

the test to determine if it has predictive validity, a psychometric property through which the success of students can be predicted.

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Annexes

Annex 1

IMDA score *(P*IMDA**)**

P	A	P	A	P	A	P	A	P	A	P	A	P	A	P	A	P	A	P	A
1	30	**37**	26	**73**	23	**109**	21	**145**	18	**181**	16	**217**	14	**253**	12	**289**	11	**325**	9
2	30	**38**	26	**74**	23	**110**	21	**146**	18	**182**	16	**218**	14	**254**	12	**290**	11	**326**	8
3	30	**39**	26	**75**	23	**111**	21	**147**	18	**183**	16	**219**	14	**255**	12	**291**	11	**327**	8
4	30	**40**	26	**76**	23	**112**	20	**148**	17	**184**	16	**220**	14	**256**	12	**292**	11	**328**	8
5	30	**41**	26	**77**	23	**113**	20	**149**	17	**185**	16	**221**	14	**257**	12	**293**	10	**329**	8
6	30	**42**	26	**78**	23	**114**	20	**150**	17	**186**	16	**222**	14	**258**	12	**294**	10	**330**	8
7	30	**43**	26	**79**	23	**115**	20	**151**	17	**187**	15	**223**	14	**259**	12	**295**	10	**331**	8
8	29	**44**	26	**80**	23	**116**	20	**152**	17	**188**	15	**224**	14	**260**	12	**296**	10	**332**	8
9	29	**45**	26	**81**	23	**117**	20	**153**	17	**189**	15	**225**	14	**261**	12	**297**	10	**333**	7
10	29	**46**	26	**82**	23	**118**	20	**154**	17	**190**	15	**226**	14	**262**	12	**298**	10		
11	29	**47**	26	**83**	23	**119**	20	**155**	17	**191**	15	**227**	13	**263**	12	**299**	10	***M_{IMDA}=17***	
12	29	**48**	26	**84**	23	**120**	20	**156**	17	**192**	15	**228**	13	**264**	12	**300**	10		
13	29	**49**	25	**85**	22	**121**	20	**157**	17	**193**	15	**229**	13	**265**	11	**301**	10		
14	29	**50**	25	**86**	22	**122**	20	**158**	17	**194**	15	**230**	13	**266**	11	**302**	10		
15	29	**51**	25	**87**	22	**123**	19	**159**	17	**195**	15	**231**	13	**267**	11	**303**	10		
16	29	**52**	25	**88**	22	**124**	19	**160**	17	**196**	15	**232**	13	**268**	11	**304**	10		
17	29	**53**	25	**89**	22	**125**	19	**161**	17	**197**	15	**233**	13	**269**	11	**305**	10		
18	29	**54**	25	**90**	22	**126**	19	**162**	17	**198**	15	**234**	13	**270**	11	**306**	10		
19	28	**55**	25	**91**	22	**127**	19	**163**	17	**199**	15	**235**	13	**271**	11	**307**	10		
20	28	**56**	25	**92**	22	**128**	19	**164**	17	**200**	15	**236**	13	**272**	11	**308**	10		
21	28	**57**	25	**93**	22	**129**	19	**165**	17	**201**	15	**237**	13	**273**	11	**309**	10		
22	28	**58**	25	**94**	22	**130**	19	**166**	16	**202**	15	**238**	13	**274**	11	**310**	10		
23	28	**59**	25	**95**	22	**131**	19	**167**	16	**203**	15	**239**	13	**275**	11	**311**	10		
24	28	**60**	25	**96**	22	**132**	19	**168**	16	**204**	15	**240**	13	**276**	11	**312**	10		
25	28	**61**	24	**97**	22	**133**	19	**169**	16	**205**	15	**241**	13	**277**	11	**313**	10		
26	28	**62**	24	**98**	22	**134**	19	**170**	16	**206**	15	**242**	13	**278**	11	**314**	10		
27	27	**63**	24	**99**	21	**135**	19	**171**	16	**207**	14	**243**	12	**279**	11	**315**	10		
28	27	**64**	24	**100**	21	**136**	19	**172**	16	**208**	14	**244**	12	**280**	11	**316**	10		
29	27	**65**	24	**101**	21	**137**	18	**173**	16	**209**	14	**245**	12	**281**	11	**317**	10		
30	27	**66**	24	**102**	21	**138**	18	**174**	16	**210**	14	**246**	12	**282**	11	**318**	9		
31	27	**67**	24	**103**	21	**139**	18	**175**	16	**211**	14	**247**	12	**283**	11	**319**	9		
32	27	**68**	24	**104**	21	**140**	18	**176**	16	**212**	14	**248**	12	**284**	11	**320**	9		
33	27	**69**	24	**105**	21	**141**	18	**177**	16	**213**	14	**249**	12	**285**	11	**321**	9		
34	27	**70**	24	**106**	21	**142**	18	**178**	16	**214**	14	**250**	12	**286**	11	**322**	9		
35	27	**71**	23	**107**	21	**143**	18	**179**	16	**215**	14	**251**	12	**287**	11	**323**	9		
36	27	**72**	23	**108**	21	144	18	**180**	16	**216**	14	**252**	12	**288**	11	**324**	9		

Annex 2

IMDA instrument

Items No	Item
1-6 (PAA)	Determine the result of the algebraic expression: $2x + 3y =$ (for $x = 1;\ y = -2$)
	Determine the result of the algebraic expression: $3a - 2b$ = (for $a = \frac{3}{5};\ b = \frac{1}{10}$)
	Indicate the value of "x" in the algebraic expression: $x = 8 + y;$ consider that: $y = 4$
	The value of "x" in the algebraic expression is searched: $8x - 8 = 6.$
	Indicate the value of "x" to achieve equality in the following algebraic operation: $-11 + 7 = x - 6$
	State the equivalent of the following algebraic expression: $4(x - 2) + 6 =$
7-12 (RP)	Indicate the number that satisfies the equality: $(a)(b + c) = (ab + ac)$
	Indicate the value of "x" in the following algebraic operation: $\frac{3x}{4} - 12 = 0$
	Equality: $r^4 = 256$ Which expression determines the value of "r"?
	Indicate the result of the algebraic sum: $4x(y - 4xy) + 12x^2y =$
	Indicate the factors corresponding to the square trinomial: $x^2 - 3x - 18$
	State the solutions to the system of simultaneous equations: $(2x + 4y = 28)$; $(-4x + 2y = -6)$
13-18 (IP)	State the term in the fifth position of the following geometric progression: 3, 9, 27,..., (...),
	Indicate the pattern of the following geometric progression: 7, 11, 15, 19, ...
	The sum of 6 consecutive numbers is 45. what should be the range of these numbers?
	what is the sum of the first 5 terms of the arithmetic progression: 15, 13, 11, ..., ...?
	To which geometric progression does the pattern correspond: $3n^2 - 2$
	Which monomial fits in the fifth position of the geometric progression: $2xy, 4xy^2, 8xy^3, \ldots, (\ldots)$?
19-24 (GC)	State the equality that provides the solution to a direct proportion problem.
	State the equality that provides the solution to the inverse proportion problem.
	From the formula $R = \frac{V}{I}$, give the appropriate equation to calculate the value of (I).
	Derived from the formula: $x = \frac{4}{(y+z)}$, indicate the appropriate equation for calculating the value of "y".
	From the formula $^{\circ}C = \frac{^{\circ}F-32}{1.8}$; give the equation to obtain the temperature at $^{\circ}F$
	State the formula to obtain the value of the height (h) of a trapezoid: $A = \frac{(B+b)h}{2}$
25-30 (ARPM)	Write the mathematical model to represent: Maria's (M) money plus one-fourth of Lupe's (L) money
	Write the mathematical model to represent: Luis (L) has 8 coins less than Paco (P)
	Write the mathematical model to represent: Juan has 15 coins more than Pedro
	Write the mathematical model to represent: writer "B" wrote 2.5 times more pages than "A"
	Write the mathematical model to represent: There are 27 students in a group and twice as many females (M) as males (M).
	Write the mathematical model for obtaining an odd number