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Artículos científicos

Análisis de la evaluación de los conocimientos matemáticos previos de los alumnos que ingresan al curso de Cálculo Diferencial durante la pandemia de covid-19

Analysis of the Assessment of Prior Mathematical Knowledge of Students Entering the Differential Calculus Course During the COVID-19 Pandemic

Análise da avaliação dos conhecimentos matemáticos prévios dos alunos que ingressam no curso de Cálculo Diferencial durante a pandemia de covid-19

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Resumen

Este trabajo se centra en caracterizar los conocimientos matemáticos previos de los alumnos que cursan la asignatura de Cálculo Diferencial con el instrumento de Rojas y Toscano (2021). Se trata de una investigación cuantitativa descriptiva transversal no experimental que contó con la participación de 162 alumnos situados en una enseñanza de emergencia debido a la pandemia de covid-19. Los resultados obtenidos muestran deficiencias de conocimientos previos enmarcados por errores conceptuales, errores procedimentales y carencia de razonamiento matemático e interpretación de datos. Dentro de ellos, errores en conceptos y habilidades matemáticas como factorización, identificación de términos semejantes, operación de fracciones tanto aritméticas como algebraicas, desarrollo de potencias y

resolución de problemas que obstaculizan e impiden el aprendizaje del cálculo diferencial. Finalmente, se propone y anexa un plan estratégico para la mejora de conocimientos previos desde la perspectiva del aprendizaje basado en problemas, que busca incidir en la innovación educativa y ser puente para el desarrollo de un aprendizaje significativo.

Palabras clave: cálculo diferencial, conocimientos previos, diagnóstico, enseñanza emergente.

Abstract

This work focuses on characterizing the prior mathematical knowledge of students taking Differential Calculus with the instrument of Rojas and Toscano (2021). This is a non-experimental cross-sectional descriptive quantitative research involving 162 students placed in emergency teaching due to the COVID-19 pandemic. The results obtained show deficiencies of previous knowledge framed by conceptual errors, procedural errors and lack of mathematical reasoning and data interpretation. Among them, errors in mathematical concepts and skills such as factoring, identification of similar terms, operation of arithmetic and algebraic fractions, development of powers and problem solving that hinder and prevent the learning of differential calculus. Finally, a strategic plan is proposed and annexed for the improvement of previous knowledge from the perspective of problem-based learning, which seeks to influence educational innovation and be a bridge for the development of meaningful learning.

Keywords: differential calculus, prior knowledge, diagnosis, emergent teaching.

Resumo

Este trabalho tem como foco caracterizar os conhecimentos matemáticos prévios dos alunos que cursam a disciplina de Cálculo Diferencial com o instrumento de Rojas e Toscano (2021). Trata-se de uma pesquisa quantitativa descritiva transversal não experimental que contou com a participação de 162 alunos localizados em uma educação emergencial devido à pandemia de covid-19. Os resultados obtidos mostram deficiências de conhecimento prévio enquadradas por erros conceituais, erros de procedimento e falta de raciocínio matemático e de interpretação dos dados. Entre eles, erros em conceitos matemáticos e habilidades como fatoração, identificação de termos semelhantes, operação de frações aritméticas e algébricas, desenvolvimento de potências e resolução de problemas que dificultam e impedem o

aprendizado do cálculo diferencial. Por fim, é proposto e anexado um plano estratégico para o aprimoramento do conhecimento prévio na perspectiva da aprendizagem baseada em problemas, que busca influenciar a inovação educacional e ser uma ponte para o desenvolvimento de uma aprendizagem significativa.

Palavras-chave: cálculo diferencial, conhecimento prévio, diagnóstico, ensino emergente.

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Introduction

This research is focused on analyzing the results of the previous knowledge that students have before taking the Differential Calculus subject in the context of emergency teaching due to the 2019 coronavirus disease (covid-19) pandemic. It should be noted that in these emergency teaching conditions the distance or remote modality prevails, but not the structure that formality demands of virtual teaching (Hodges, Moore, Lockee, Trust and Bond, 2020). It is also necessary to point out that this work is based on the fact that the teacher is the guiding agent so that learning takes place in accordance with the objectives set by the educational institution. And for the same reason, it is required that the previous knowledge and abilities corresponding to mathematics be the most adequate possible to satisfy the academic objectives that the same curricular program demands.

Mexico, according to the results of the Population and Housing Census (National Institute of Statistics and Geography [Inegi], 2021), ranks 11th in population worldwide, with a little over 126 million inhabitants. And while it boasts a 98.7% literacy rate among 15-24 year olds, only 45.3% of Mexicans in that range attend school. In terms of technological coverage, 52.1% of Mexican private homes have internet, only 37.6% of homes have a computer and 87.5% a cell phone. Unfortunately, 52.4 million inhabitants live in poverty and 9.3 million in extreme poverty, of which 21.1 million people suffer from educational lag (Coneval [National Council for the Evaluation of Social Development Policy], 2018). To this we must add the havoc that the pandemic came to cause in the educational sphere.

Since March 16, 2020, Mexican students, to safeguard their health, have been subjected to an emergency teaching by the federal and state authorities of Mexico. Given the nature of mathematics and its own difficulties in both teaching and learning and the very complexity of this science, there is an extensive record of research carried out, most of them under a face-to-face teaching model (Artigue , 1988; Cornu, 1991; Cottrill et al., 1996; Rojas,

2018, 2019, 2020a, 2020b; Tall, 1995); Now, under the emerging scheme, it is important that previous knowledge persist at all times in order to build new knowledge, skills and abilities through interaction with educational technologies (Cabero, 2007; Herrera and Fénnema, 2011; Mesa, 2012; Morantes, Dugarte and Herrera, 2019; Rojas, 2017; Rojas and Toscano, 2018; Sangrà, 2006), which is sought with this work.

Designed to be applied during the covid-19 pandemic, the Rojas and Toscano (2021) instrument used in this project identifies the previous knowledge that the student has and serves as an aid to identify academic lags in both procedural and conceptual skills. Said instrument has an internal consistency reliability coefficient of 0.807, which indicates that the results can be reproduced in different samples without great bias on the part of the participants. (Rojas y Toscano, 2021).

Theoretical framework and background

When we talk about mathematics, by its nature, we talk about constructivism. Piaget, who developed the theory of the nature of knowledge and how participants come to construct, develop and apply that knowledge, conceives cognitive development as a progressive reorganization of mental processes taking into account biological maturation and environmental experimentation. On the other hand, Vygotsky developed the concept of the zone of proximal development, which refers to the skills that an individual can have with the assistance of another more expert but cannot perform without him. He also considers the importance of peer interaction to develop skills, that is, he emphasizes social interaction (Lourenço, 2012). While Ausubel, from a cognitive approach to meaningful learning, conceptualizes learning as the restructuring of perceptions, ideas and concepts and relates prior knowledge and new information (Ndjatchi, 2019). Thus, "prior knowledge is a principle of constructivist pedagogy that, based on cognitive theories, posits that the subject is capable of developing their own knowledge construction processes" (Pérez, 2019, p. 4).

In the same way, Martínez, Giné, Fernández, Figueiras and Deulofeu (2011) mention that temporary connections make it possible to learn new or complex situations and occur between previous and future knowledge. These temporary connections make it possible to establish a relationship between skills, competencies and cognitive development with experiences already lived and, in turn, establish and guide new concepts to open the way to

new skills, competencies and greater cognitive development. Learning becomes significant when there is a symbiosis between previous and future knowledge.

> Learning occurs when "discrete" changes in knowledge are evidenced, that is, "jumps" occur in what the subject knew and the "new" knowledge that he acquires when the information is stored in long-term memory in a systematic way. , ordered, structured, that is, in an organized way and this is achieved when that information is significant, that is, when it has some value for the subject, when it is important for him, either because it is necessary, useful or relevant (Mota y Valles, 2015, p. 88).

From the constructivist conception, the student always has previous knowledge regarding the new knowledge that could be offered, since the knowledge is built or reconstructed according to the experience according to its own maturity and environmental experience, and although the learning contents can be a criterion for determine previous knowledge, it is preponderant to investigate the students.

> Cognitive constructivism conceives thought, learning and psychological processes in general as phenomena that take place in people's minds. In the minds of the students their representations are stored —schemas or mental models— of the physical and social world, so that learning consists fundamentally in relating the new information or experiences with the already existing representations, which can give rise, under certain circumstances, to an internal process of revision and modification of these representations, or to the construction of new ones through the reorganization and internal differentiation of the already existing representations. (Coll, 2014, p.160).

However, the decision of what prior knowledge the student requires must fall mainly on the teacher, based on the academic program to be taught. As an expert and professional in the field, he must be able to discern and establish the minimum requirements necessary for the cognitive process to be carried out.

To investigate prior knowledge, there are several techniques, for example, López (2009) mentions that they can answer open, closed or multiple-choice questionnaires, solve problem situations, work in small discussion groups, among others; and it stands as an activating agent of previous knowledge for students, who should promote, according to their maturity, the awareness of their ideas and seek to justify their answers.

Within the works that have been in charge of this issue in the field of mathematics, we can point to the study by Mota and Valles (2015), where the importance of the structured study of the previous knowledge of the students who recently they enter the university in the area of mathematics; the identification of previous knowledge carried out by Ndjatchi (2019) with engineering students in Computer Systems; the predominance of the reflective style found by Alducin and Vázquez (2016), who also detected that there is a correlation between self-assessment and grades in mathematics and that the behavior of the students, according to the styles, is variable in the different subjects; We also have the study of the vertiginous leap from high school to university by Huidobro, Méndez and Serrano (2010), a process where the main obstacle to overcome is overcoming mathematics in the first year of university; the analysis of the gaps in basic mathematical knowledge and skills of the students of the Higher Polytechnic School by Castro, García, Sirvent, Martín and Rodríguez (2019), who refer that this type of diagnosis of basic knowledge and gaps allows defining and implementing strategies of remediation and tutoring that help facilitate academic success and, thereby, reduce the dropout rate.

Objective

Characterize the prior mathematical knowledge of students taking the Differential Calculus subject during the covid-19 pandemic with the instrument of Rojas and Toscano (2021) and design a strategic plan to improve prior knowledge that allows incorporating educational innovation linking the technology.

Methodology

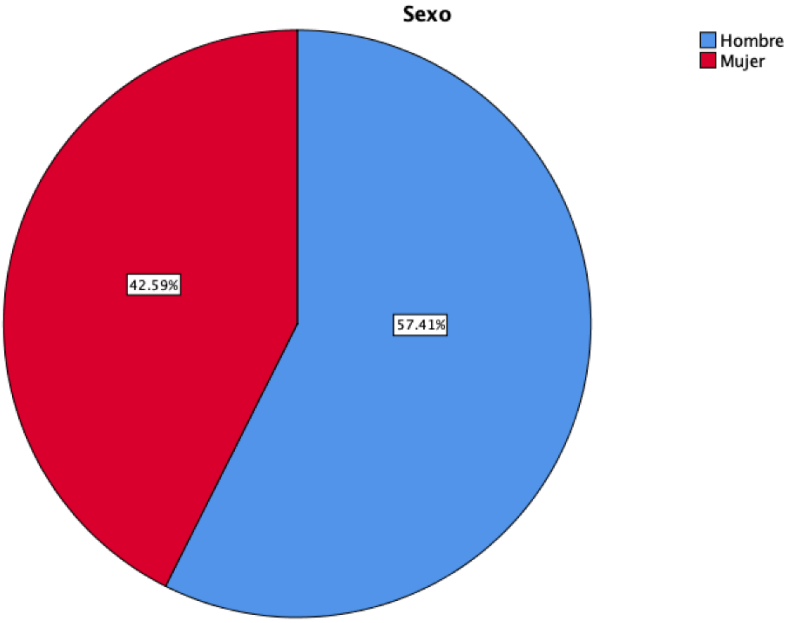
With the purpose of characterizing the previous mathematical knowledge that students have in the 2020-2021 cycle of the Engineering and Architecture Baccalaureate Section 01 and the Chemical Biological Baccalaureate Section 01 of the Colegio Primitivo y Nacional de San Nicolás de Hidalgo, as well as students of the degree in Biotechnology sections 4 and 3 prior to the course of Differential Calculus, whose age ranges between 17 and 18 years, there was a participation of 162 students, 93 men and 69 women. It should be noted that, from the declaration of contingency and until the development of this work, the teaching process of these students was virtual with the help of Google Suite tools.

The Rojas and Toscano (2021) instrument was applied, which has an internal consistency reliability coefficient of 0.807 and is structured to reflect prior academic knowledge such as arithmetic ability and algebraic ability; in such a way that it is identified with the practice in problem solving and that allows the construction of mathematical knowledge; 23 reagents were applied, nine corresponding to the algebra category and 14 in the algebra category. As a means of data capture, Google Forms was used, due to health and convenience conditions, with multiple-choice reagent types of five elements. It was requested not to use calculators or cell phones during the application of the instrument. This is a quantitative research with a type of non-experimental cross-sectional descriptive study, since we limit ourselves to the analysis of the characteristics in a population in a cut of time. (Hernández, Fernández y Baptista, 2010; Montero y León, 2002)

Results

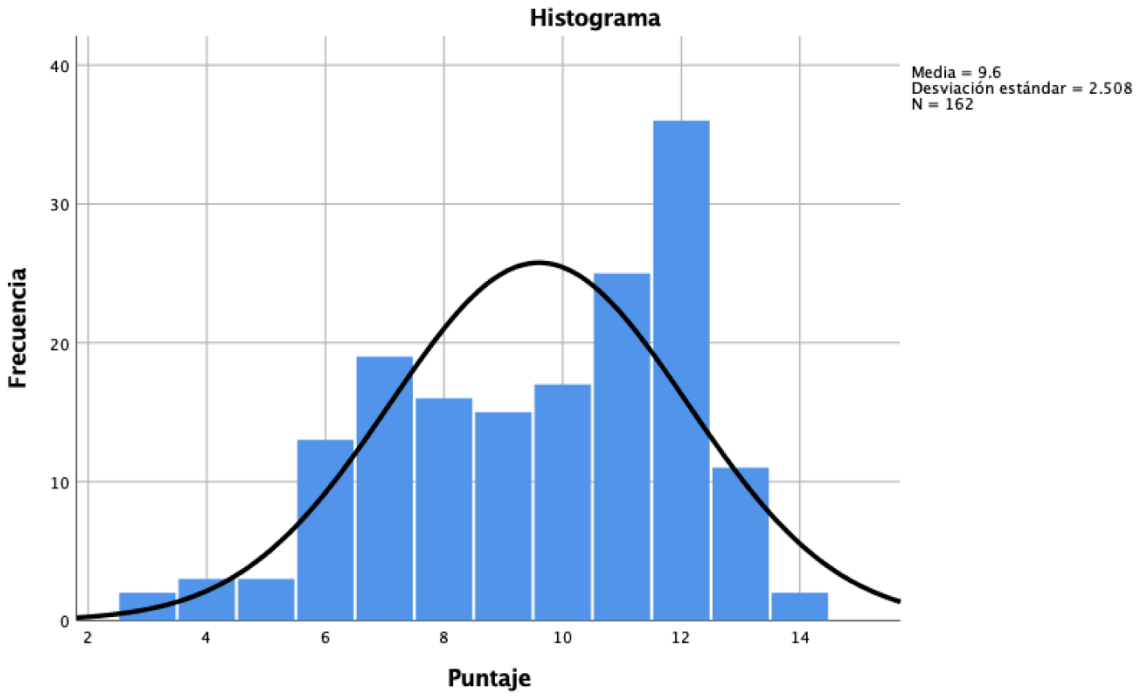
Regarding gender, 57.4% of the participants were men and 42.6% women, as can be seen in Figure 1. In arithmetic competition, 81.4% of the participants have the skill corresponding to the computation of addition and subtraction with rational numbers. , while 91.9% have a clear ability to calculate the product of fractions; however, only 68.6% express the clarity to calculate the division of fractions and 55.7% perform mixed fraction operations successfully. Finally, 87.7% correctly relate the power of a number and 98.8% the notion of percentage. Within mathematical logic, 60.5% carry out logical reasoning to carry out an activity. In addition, 74.5% show the ability to solve arithmetic problems with decimal numbers, but only 55.4% of the sample correctly answer the problems with rational numbers and barely 12.3% demonstrate the ability to solve problems related to the calculation of percentages.

Figure 1. Sex of the participants



Source: Own elaboration

Figure 2. Distribution of the score obtained in the arithmetic category



Source: self made

Figure 2 shows that the most frequent score obtained was 12 points out of the 14 possible to obtain; 36 respondents obtained this score, only two of the respondents presented a perfect score and also two respondents the minimum score, which was three.

Table 1. Statistics of the score obtained in the arithmetic category

N	Válido	162
	Perdidos	0
Media	9.60	
Mediana	10.00	
Moda	12	
Desviación	2.508	
Varianza	6.291	

Source: Own elaboration

Table 2. Score obtained in the arithmetic category

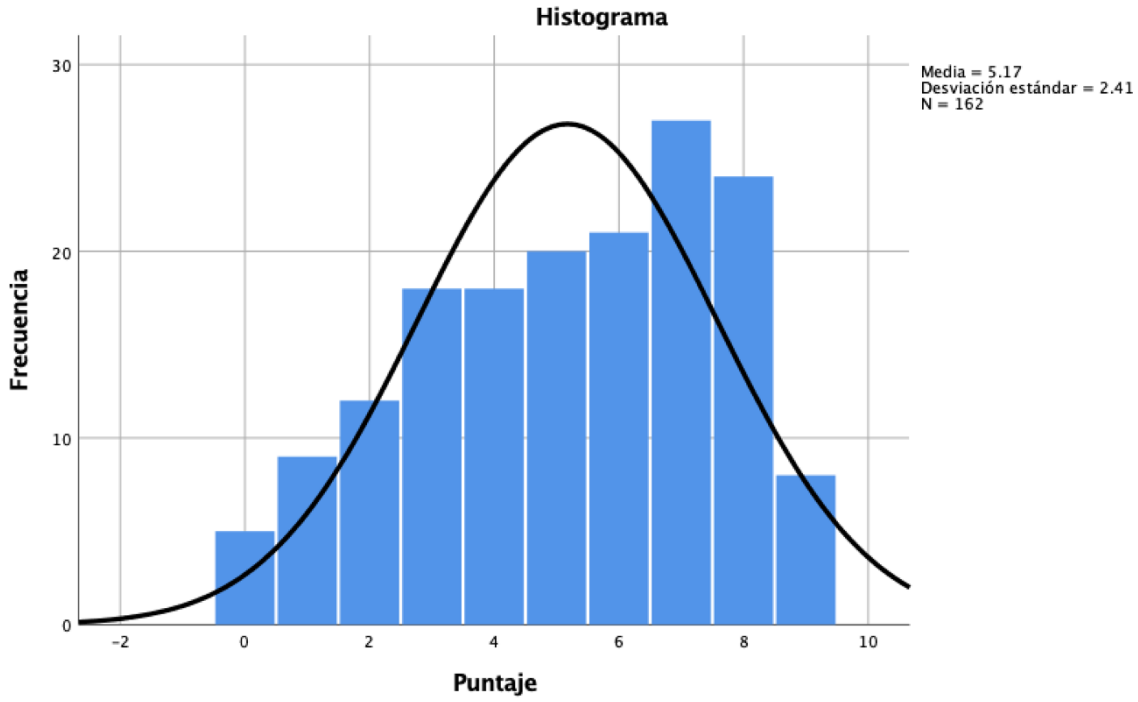
	Frecuencia	Porcentaje	Porcentaje válido	Porcentaje acumulado
3	2	1.2	1.2	1.2
4	3	1.9	1.9	3.1
5	3	1.9	1.9	4.9
6	13	8.0	8.0	13.0
7	19	11.7	11.7	24.7
8	16	9.9	9.9	34.6
9	15	9.3	9.3	43.8
10	17	10.5	10.5	54.3
11	25	15.4	15.4	69.8
12	36	22.2	22.2	92.0
13	11	6.8	6.8	98.8
14	2	1.2	1.2	100.0
Total	162	100.0	100.0	

Source: Own elaboration

A mean of 9.6/14 and a mean value of 10/14 was obtained in the arithmetic category.

In the algebraic part, the results emanating from the instrument reflect that 53.8% of the respondents exhibit the ability to simplify algebraic expressions of medium complexity, 75.5% correctly develop a squared binomial, 48.1% correctly find the roots of an algebraic equation and only 34.6 % of respondents understand the meaning of a root of a polynomial; 61% recognize and present the ability to factor by at least one method and 60% of the participants correctly managed to solve problems related to algebra.

Figure 3. Scores obtained in the Algebra category



Source: Own elaboration

Table 3. Statistics of the score obtained in the algebra category

N	Válido	162
	Perdidos	0
Media	5.17	
Mediana	5.00	
Moda	7	
Desviación	2.410	
Varianza	5.808	

Source: Own elaboration

Table 4. Score obtained in the algebra category

	Frecuencia	Porcentaje	Porcentaje válido	Porcentaje acumulado
0	5	3.1	3.1	3.1
1	9	5.6	5.6	8.6
2	12	7.4	7.4	16.0
3	18	11.1	11.1	27.2
4	18	11.1	11.1	38.3
5	20	12.3	12.3	50.6
6	21	13.0	13.0	63.6
7	27	16.7	16.7	80.2
8	24	14.8	14.8	95.1
9	8	4.9	4.9	100.0
Total	162	100.0	100.0	

Source: Own elaboration

Figure 3 shows the scores obtained by the participants regarding algebraic management. The highest frequency score is seven out of a total of nine possible points, which corresponds to 27/162 respondents; 8 of the 162 respondents obtained a perfect score of nine, that is, the maximum score; five respondents did not get points. Thus, the algebra category has a mean of 5.17 and a median of 5.0 with a standard deviation of 2.41.

Discussion

In the field of arithmetic it is presumed that the computation of integers, decimals and fractions is completely mastered by a student who is about to enter a class in differential calculus, which is a part of infinitesimal calculus and mathematical analysis, and where the main study are the variations; but operations with rational numbers remain a difficulty that students cannot overcome. The addition and subtraction of fractions represent the greatest ability to perform the computation, but not in a generalized way and the one that presents the greatest difficulty is the division of fractions, whether proper or improper, where it should not be surprising, since more than 90% of the respondents successfully solved the product of fractions, which suggests that there is a lack of the notion of the multiplicative inverse. This is not surprising, since fractions bring with them an inherent difficulty in understanding the relationship a/b when that of the whole number is less difficult, since the relationships between their operations are different. These data are similar to those of the study by Ndjatchi (2019), referring to the management of elementary algebra with students of Computer Systems Engineering, but referring to prior knowledge for learning complex numbers.

The teacher's experience also interferes when giving a good explanation of the meaning of a fraction and performing operations. Likewise, it is considerable to note that the teaching of fractions in the Asian continent is persevered more than in the American continent, that its management is fundamental for more advanced areas of mathematics and other sciences and that unfortunately the social opinion regarding its difficulty creates a barrier for the student to understand its meaning and use (Cai and Silver, 2020; Son, 2020; Stevenson and Stigler, 1999; Watanabe, Lo and Son, 2017). Regarding empowerment, it follows that they recognize the meaning of this, however, in the development to solve problems it is also glimpsed that the properties of empowerment are not part of their competencies. It should be noted that, for problem solving, the difficulty in identifying the unknown, the difficulty in analyzing the problem or statement, difficulty in logical mathematical reasoning persists, and they do not verify that the solution is consistent with the problem.

Due to the nature of the category to be evaluated, it is very unlikely that the minimum score to be obtained was zero, but, despite this, two respondents were found with a score of three, which reflects their little or no preparation, which could contribute to the construction of a new learning based on variations. In table 2, in correspondence with table 1, it is observed

that 24.7% of the population, that is, 44 respondents de facto show that they are candidates not to pass the Differential Calculus subject; the lack of arithmetic and algebraic skills, abilities and knowledge point to school failure, which coincides with the study of the lack of knowledge and basic mathematical skills of the students of the Higher Polytechnic School of Castro et al. (2019) and the attitude of students towards mathematics.

While in the algebraic part, it appears that half of the respondents manage to reduce simplifications of algebraic expressions satisfactorily. It should be emphasized that reducing an expression or equation to the simplest terms possible is a core part of learning algebra. Within that same category, the development of binomials to different powers is one of the most used tools in more advanced mathematics classes; In this regard, three quarters of the sample successfully manage to develop a squared binomial, but just under 10% manage to develop a binomial to higher powers, that is, the link with arithmetic knowledge. Regarding finding solutions to algebraic equations of second degree and first degree, just under 50% of the respondents successfully obtained them, a figure that was considerably reduced in algebraic equations of third degree, however, obtaining roots is not clearly linked to their graphic interpretation, since a fifth of the participants stated that the roots are the intersection with the axis of the ordinates. This situation is extremely important for them to be able to contextualize the limit and the derivative from a graphical perspective of a problem, or for interpretations of domains and images of functions that give rise to the construction of subsequent knowledge. In the study by López (2009) it is stated that learning depends on the confluence of different factors and that the process of concepts requires a gradual change.

In the factorization dimension, an extremely important strategy for the reduction of terms and that facilitates the handling of algebraic expressions, a phenomenon similar to that of the reduction of terms arises: just over half of those involved in this project have the ability to factor by at least one method. It is to be expected that this result of this dimension is consistent with that of the reduction of terms, because despite the fact that factorization implies expression in terms of products, it is linked to the identification of similar terms. Consequently, more than half fail to understand the notion of it and notoriously confuse a variable with a constant, or if the variable is raised to some power, so they assume that they can be added with those that are not, in addition the rules of powers are not clear when the variables are added or multiplied, since a very marked error is that a+a=a^2, as Barroso and Rodríguez (2007) have similarly reflected. In other words, the student is not able to group mathematical problems according to their deep structure, lacking adequate cognitive

schemes, since having them facilitates the generalization of resolution strategies and mastery of some mathematical elements, not However, it only manages to use them in problems that explicitly indicate it. Under problem solving using algebra, the same percentage that have factoring ability have problem solving ability. It would be expected that this percentage would be a little lower, since many times, due to their very nature, they require a wide range of strategies (Juidías and Rodríguez, 2007; Rico, 1998; Socas, Hernández and Palarea, 2014). Despite this, having the ability to factor allows you to recognize the structure of a problem and solve it intrinsically with a logical mathematical procedure.

As can be seen from figure 3, 82 students achieved a score less than or equal to five. Obtaining positive results at the end of the Differential Calculus course would entail an arduous process, not only for the teacher, but for the student himself. As can be inferred from table 3, related to table 4 in the algebra category, the percentage of school failure (50.6%) is more than double compared to the algebra category (24.7%).

Conclusions

From the objective of this work, it has been tried to characterize the previous knowledge that the student has when entering the course of Differential Calculus and, with it, to expose the weaknesses in the algebraic and arithmetic management, with the objective that the academic achievement is satisfied to the to join this subject, with the aspiration of designing a strategic plan to compensate for said lack of mathematical skills and abilities, as well as to remedy weaknesses such as skills, knowledge or abilities manifested.

The abuse of mathematical exercises that seek to awaken or develop a mathematical ability leads to mechanization in which students only seek the solution immediately and downplay the process or plan to find a solution. This, in turn, leads to the evaluation system of the institutions or the teacher being used to obtain the result correctly, which affects the student to trace various strategies, even if they are not mathematical, such as the chance, intuition, trial and error to solve a problem or exercise, so that their demand in the study of mathematics is limited by making the minimum effort. In this way, the process of learning to learn is left aside; the teacher does not encourage this process to take place and on many

occasions blames too much the responsibility, the ability, the effort on the part of the student to learn mathematics or the environment from which he comes.

Teachers who try to remedy or replace in a very short time the conceptual or procedural deficiencies that students present also seek to complete an ongoing academic program and comply with the planning, control and supervision of learning processes.

The problem is aggravated when the pandemic enters as a variable, since the teacher must strengthen or develop competence in mobile devices, as well as the search for digital platforms that allow them to function more easily and benefit learning; he must also show ability to solve technical difficulties of any kind (hardware or software) that arise during his teaching process.

On the student side, not all of them handle technological tools. In fact, despite not being the study objective of this work, it should be noted that they present difficulty in scanning papers, using an equation editor through the Word text processor, attaching images to the G Suite Classroom platform, taking good photos oriented and not "moved", writing an email where the subject field is confused with the mail field, as well as the lack of skill in using a digital graphing machine and the proper use of the microphone mute. Considering that when students have digital tools they also have the knowledge and skills leads to an even greater difficulty for the teacher to carry out the teaching-learning process, since their work is diversified between mathematics facilitator, device and platform technician and as digital literacy.

Prior knowledge deficiencies were characterized by conceptual errors, procedural errors, and mathematical reasoning; the lack of prior knowledge, such as mathematical concepts and skills such as factoring, identification of similar terms, operation of both arithmetic and algebraic fractions, development of powers and problem solving, are tasks that must be carried out with the "help" of technological and personal tools such as tutoring, advice, special courses aimed at the creation and development of study habits, which should be a priority in any educational institution, supported by planning, development and evaluation of said programs and oriented, not only to a face-to-face environment , but also virtual, seeking self-directed, self-regulated and autonomous learning that contributes to cognitive maturity.

Drawing up a strategic plan consists of identifying the objective that you want to achieve and forging a path to achieve it. As a strategic plan under a project-based

methodology for the improvement of previous knowledge in mathematics, what is presented in table 3 is suggested.

Table 3. Strategic plan for the improvement of prior knowledge based on PBL

1	Sesiones de coordinación de contenidos entre docentes. El análisis, identificación de las características propias de la escuela y los alumnos y la reflexión son parte sustancial para establecer mecanismos de mejora.
2	Propuesta de proyectos multidisciplinarios que involucren contenidos matemáticos (aritméticos, algebraicos).
3	Puesta en marcha de proyectos incluyendo la escritura científica (ensayos, monografías, etc).
4	Evaluar resultados.
5	Creación de una feria científica multidisciplinaria con proyectos creados y desarrollados por alumnos con contenido matemático vinculando la tecnología.
6	Presentación de modelos con sustentación documentada con pertinencia matemática representada a través de un dispositivo digital.
7	Evaluar resultados.
8	Selección de trabajos para publicación en revistas de divulgación.

Source: self made

Future lines of research

It follows from this study and it is interesting to investigate if there is a correlation between the students who presented deficiencies in previous knowledge of mathematics and the students who did not pass the Differential Calculus course under an intervention with graphing and algebraic calculators such as Desmos, Geogebra, etc. , or on mathematization (Rojas, 2018, 2020b) and its relationship under the teaching of the concept of limit with the

didactic sequences designed by Rojas (2015), as well as the conceptions indicated by Sierra et al. (2000).

References

Alducin, J. M. y Vázquez, A. I. (2016). Autoevaluación de conocimientos previos y rendimiento según estilos de aprendizaje en un grado universitario de edificación. *Formación Universitaria*, *9*(2), 29-40. Recuperado de https://doi.org/10.4067/S0718-50062016000200004.

Artigue, M. (1988). Ingénierie didactique. *Recherches en Didactique des Mathématiques*, *9*(3), 281-308.

Cabero, J. (2007). Las necesidades de las TIC en el ámbito educativo: oportunidades, riesgos y necesidades. *Tecnología y Comunicación Educativas*, *21*(45), 4-19. Recuperado de http://investigacion.ilce.edu.mx/tyce/45/articulo1.pdf.

Cai, J. and Silver, E. A. (2020). Brief Report: Solution Processes and Interpretations of Solutions in Solving a Division-with-Remainder Story Problem: Do Chinese and U. S. Students Have Similar Difficulties? *Journal for Research in Mathematics Education, 26*(5). Retrieved from https://doi.org/10.5951/jresematheduc.26.5.0491.

Castro, M. de los A., García, P. A., Sirvent, A., Martín, J. A. y Rodríguez, F. (2019). Actitudes hacia las Matemáticas, conocimientos previos y resultados de evaluación: un estudio en primer curso de titulaciones de Ingeniería. En Roig-Vila, R. (ed.), *Investigación e innovación en la enseñanza superior. Nuevos contextos, nuevas ideas* (pp. 55-65). Barcelona, España: Octaedro.

Coll, C. (2014). Constructivismo y educación: la concepción constructivista de la enseñanza y del aprendizaje. En Coll, C., Palacios, J. y Marchesi, A. (eds.), *Desarrollo psicológico y educación 2*. Psicología de la educación escolar (pp. 157-188). Madrid, España: Alianza Editorial.

Consejo Nacional de Evaluación de la Política de Desarrollo Social [Coneval]. (2018). Pobreza en México. Resultados de pobreza en México 2018 a nivel nacional y por entidades federativas. Recuperado de https://www.coneval.org.mx/Medicion/MP/Paginas/Pobreza-2018.aspx.

Cornu, B. (1991). Limits. In Tall, D. (ed.), *Advanced Mathematical Thinking* (pp. 153-166). United States: Kluwer.

Cottrill, J., Dubinsky, E., Nichols, D., Schwingendorf, K., Thomas, K. and Vidakovic, D. (1996). Understanding the limit concept: Beginning with a coordinated process scheme. *Journal of Mathematical Behavior*, *15*(2), 167-192. Retrieved from https://doi.org/10.1016/S0732-3123(96)90015-2.

Hernández, R., Fernández, C. y Baptista, P. (2010). *Metodología de la investigación* (5.ª ed.). México: McGraw-Hill.

Herrera, S. y Fénnema, M. (2011). Tecnologías móviles aplicadas a la educación superior. Ponencia presentada en el XVII Congreso Argentino de Ciencias de la Computación. La Plata, 4 de agosto de 2017.

Hodges, C., Moore, S., Lockee, B., Trust, T. y Bond, A. (2020). La diferencia entre la enseñanza remota de emergencia y el aprendizaje en línea. En Neira, P., Rodríguez, C. y Villanueva, J. (coords.), *Enseñanza remota de emergencia: textos para la discusión* (pp. 10-22). The Learning Factor.

Huidobro, J., Méndez, A. y Serrano, M. (2010). Del bachillerato a la universidad: las matemáticas en las carreras de ciencias y tecnología. *Aula Abierta*, *38*(1), 71-80.

Instituto Nacional de Estadística y Geografía [Inegi]. (2021). Censo de Población y Vivienda 2020. México: Instituto Nacional de Estadística y Geografía. Recuperado de http://censo2020.mx/.

Juidías, J. y Rodríguez, I. (2007). Dificultades de aprendizaje e intervención psicopedagógica en la resolución de problemas matemáticos. *Revista de Educación*, (342), 23-35. Recuperado de https://idus.us.es/handle/11441/60933.

López, J. A. (2009). La importancia de los conocimientos previos para el aprendizaje de nuevos contenidos. *Innovación y Experiencias Educativas*, (16), 1-14. Recuperado de https://archivos.csif.es/archivos/andalucia/ensenanza/revistas/csicsif/revista/pdf/Numero_16/JOSE%20ANTONIO_LOPEZ_1.pdf.

Lourenço, O. (2012). Piaget and Vygotsky: Many resemblances, and a crucial difference. *New Ideas in Psychology*, *30*(3), 281-295. Retrieved from https://doi.org/10.1016/j.newideapsych.2011.12.006.

Martínez, M., Giné, C., Fernández, S., Figueiras, L. y Deulofeu, J. (2011). El conocimiento del horizonte matemático: más allá de conectar el presente con el pasado y el futuro. En Marín, M., Fernández, G., Blanco, L. J. y Palarea, M. (eds.), *Investigación en*

educación matemática XV (pp. 429-438). Ciudad Real, España: Sociedad Española de Investigación en Educación Matemática.

Mesa, W. (2012). Las TIC como herramientas potenciadoras de equidad, pertinencia e inclusión educativa. *Revista Ciencia Tecnología Sociedad*, *4*(7), 61-77. Recuperado de https://papers.ssrn.com/sol3/papers.cfm?abstract_id=3528657.

Montero, I. y León, O. G. (2002). Clasificación y descripción de las metodologías de investigación en Psicología. *International Journal of Clinical and Health Psychology*, *2*(3), 503-508.

Morantes, G., Dugarte, E. y Herrera, J. (2019). Perfil del aprendiz estratégico para el estudio de Cálculo Diferencial mediado por las TIC. *Revista Logos, Ciencia & Tecnología*, *11*(3), 152-167. Recuperado de https://doi.org/10.22335/rlct.v11i3.864.

Mota, D. J. y Valles, R. E. (2015). Papel de los conocimientos previos en el aprendizaje de la matemática universitaria. *Acta Scientiarum. Education*, *37*(1), 85-90. Recuperado de https://doi.org/10.4025/actascieduc.v37i1.21040.

Ndjatchi, M. K. C. (2019). Conocimientos previos de números complejos en ingeniería. *Ciencia, Docencia y Tecnología*, *30*(58), 305-329. Recuperado de https://doi.org/10.33255/3058/477.

Pérez, A. (2019). Conocimientos previos e intervención docente. *Acta Educativa*, (19), 1-30. Recuperado de https://revista.universidadabierta.edu.mx/publicacion-19/.

Rico, L. (1998). Errores en el aprendizaje de las matemáticas. En Kilpatrick, J., Gómez, P. y Rico, L. (eds.), *Educación matemática. Errores y dificultades de los estudiantes. Resolución de problemas. Evaluación. Historia*. Bogotá, Colombia: una empresa docente.

Rojas, E. R. (2015). Secuencias didácticas para la enseñanza del concepto de límite en el cálculo. *Revista Internacional de Ciencia, Matemáticas y Tecnología*, *2*(2), 63-76. Recuperado de http://funes.uniandes.edu.co/15392/1/Rojas2016Secuencias.pdf.

Rojas, E. R. (2017). La formación profesional y la enseñanza con tecnología. En *Reflexiones sobre innovación educativa en la Universidad Michoacana de San Nicolás de Hidalgo* (pp. 85-102). México: Universidad Michoacana de San Nicolás de Hidalgo.

Rojas, E. R. (2018). Mathematization: A teaching strategy to improve the learning of Calculus. *RIDE Revista Iberoamericana para la Investigación y el Desarrollo Educativo*, *9*(17).

Rojas, E. R. (2019). Diseño de estrategia de apertura para la interpretación gráfica-analítica a través de Desmos como preparación para el aprendizaje del cálculo diferencial. *RIDE Revista Iberoamericana para la Investigación y el Desarrollo Educativo*, *10*(19). Recuperado de https://doi.org/10.23913/ride.v10i19.493.

Rojas, E. R. (2020a). Análisis de la percepción de los profesores en activo referente al uso de la tecnología en la Matemática. *Polyphōnia. Revista de Educación Inclusiva*, *4*(2), 167-196.

Rojas, E. R. (2020b). La comprensión de conceptos fundamentales del cálculo mediante Desmos. Una intervención. *RIDE Revista Iberoamericana para la Investigación y el Desarrollo Educativo*, *10*(20), 1-15. Recuperado de https://doi.org/https://doi.org/10.23913/ride.v10i20.672.

Rojas, E. R. y Toscano, J. (2018). Hablemos de tecnología, inclusión e innovación educativa en los albores de la cuarta revolución industrial. En Fernández, B. y González, C. (coords.), *Las TIC como herramientas para la inclusión en la educación universitaria* (pp. 69-84). México: Porrúa.

Rojas, E. R. y Toscano, J. (2021). Instrumento para evaluar los conocimientos matemáticos previos para la enseñanza del concepto de límite durante la pandemia SARS-CoV-2. *RIDE Revista Iberoamericana para la Investigación y el Desarrollo Educativo*, *11*(22). Recuperado de https://doi.org/10.23913/ride.v11i22.953.

Sangrà, A. (2006). Educación a distancia, educación presencial y usos de la tecnología: una tríada para el progreso educativo. *Edutec. Revista Electrónica de Tecnología Educativa,* (15). Recuperado de https://doi.org/10.21556/edutec.2002.15.541.

Sierra, M., González, M. y López, C. (2000). Concepciones de los alumnos de bachillerato y curso de orientación universitaria sobre límite funcional y continuidad. *Relime. Revista Latinoamericana de Investigación en Matemática Educativa*, *3*(1), 71-86.

Socas, M., Hernández, J. y Palarea, M. M. (2014). Dificultades en la resolución de problemas de Matemáticas de estudiantes para profesor de educación primaria y secundaria. En González, J. L., Fernández, J. A., Castro, E., Sánchez, M. T., Fernández, C., Lupiáñez, J. L. y Puig, L. (eds.), *Investigaciones en pensamiento numérico y algebraico e historia de las matemáticas y educación matemática - 2014* (pp. 145-154). Málaga:Departamento de Didáctica de las Matemáticas, de las Ciencias Sociales y de las Ciencias Experimentales y SEIEM.

Son, J.-W. (2020). A global look at math instruction. *Teaching Children Mathematics*, *17*(6), 360-370. Retrieved from https://doi.org/10.5951/tcm.17.6.0360.

Stevenson, H. W. y Stigler, J. W. (1999). ¿Por qué los escolares de Asia Oriental tienen alto rendimiento académico? *Estudios Públicos*, (76), 297-357. Recuperado de https://www.cepchile.cl/cep/site/artic/20160303/asocfile/20160303184441/rev76_stevenson.pdf.

Tall, D. (1995). Cognitive Growth in Elementary and Advanced Mathematical Thinking. Conference of the International Group for the Psychology of Learning Mathematics. Recife, July 1995.

Watanabe, T., Lo, J.-J., and Son, J.-W. (2017). Intended Treatment of Fractions and Fraction Operations in Mathematics Curricula from Japan, Korea, and Taiwan. In Son, J.-W. Watanabe, T. and Lo, J.-J. (eds.), *What Matters? Research Trends in International Comparative Studies in Mathematics Education* (pp. 33-61). Cham, Switzerland: Springer. Retrieved from https://doi.org/10.1007/978-3-319-51187-0_2.

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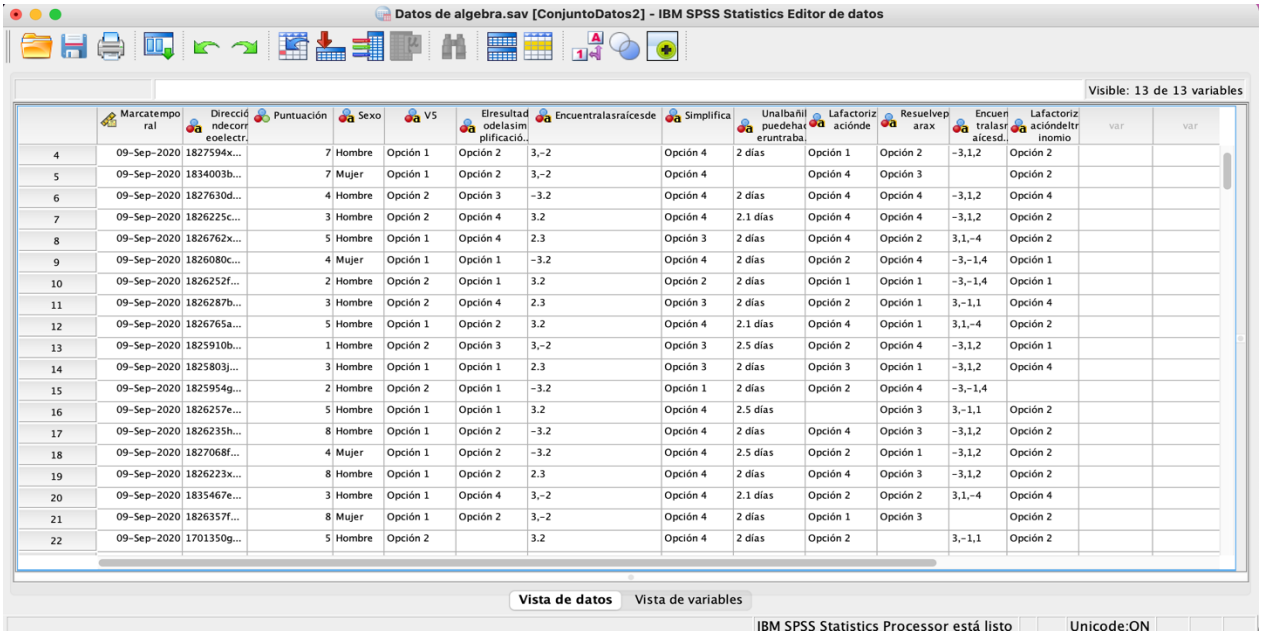
Anexo 1. Recolección de datos

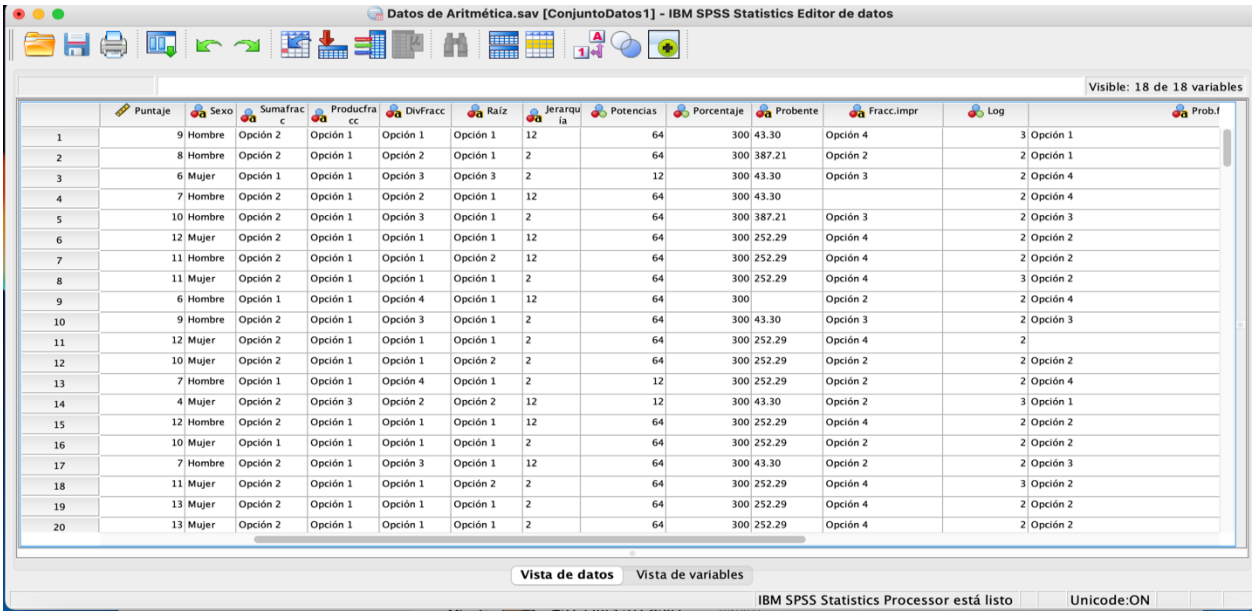
Figura 4. Datos procesados en SPSS versión 25 del cuestionario referente a la categoría de álgebra.



	Marcatemporal	Direcciónde corr eoelectr.	Puntuación	Sexo	V5	Elresultadodelasimplificació..	Encuentralasraícesde	Simplifica	Unalbañilpuedehacereruntraba.	Lafactorizaciónde	Resuelvearax	Encuentralasraícesd.	Lafactorizaciónde ltrinomio	var	var
4	09-Sep-2020	1827594x...	7	Hombre	Opción 1	Opción 2	3,-2	Opción 4	2 días	Opción 1	Opción 2	-3,1,2	Opción 2		
5	09-Sep-2020	1834003b...	7	Mujer	Opción 1	Opción 2	3,-2	Opción 4		Opción 4	Opción 3		Opción 2		
6	09-Sep-2020	1827630d...	4	Hombre	Opción 2	Opción 3	-3.2	Opción 4	2 días	Opción 4	Opción 4	-3,1,2	Opción 4		
7	09-Sep-2020	1826225c...	3	Hombre	Opción 2	Opción 4	3.2	Opción 4	2.1 días	Opción 4	Opción 4	-3,1,2	Opción 2		
8	09-Sep-2020	1826762x...	5	Hombre	Opción 1	Opción 4	2.3	Opción 3	2 días	Opción 4	Opción 2	3,1,-4	Opción 2		
9	09-Sep-2020	1826080c...	4	Mujer	Opción 1	Opción 1	-3.2	Opción 4	2 días	Opción 2	Opción 4	-3,-1,4	Opción 1		
10	09-Sep-2020	1826252f...	2	Hombre	Opción 2	Opción 1	3.2	Opción 2	2 días	Opción 1	Opción 1	-3,-1,4	Opción 1		
11	09-Sep-2020	1826287b...	3	Hombre	Opción 2	Opción 4	2.3	Opción 3	2 días	Opción 2	Opción 1	3,-1,1	Opción 4		
12	09-Sep-2020	1826765a...	5	Hombre	Opción 1	Opción 2	3.2	Opción 4	2.1 días	Opción 4	Opción 1	3,1,-4	Opción 2		
13	09-Sep-2020	1825910b...	1	Hombre	Opción 2	Opción 3	3,-2	Opción 3	2.5 días	Opción 2	Opción 4	-3,1,2	Opción 1		
14	09-Sep-2020	1825803j...	3	Hombre	Opción 1	Opción 1	2.3	Opción 3	2 días	Opción 3	Opción 1	-3,1,2	Opción 4		
15	09-Sep-2020	1825954g...	2	Hombre	Opción 2	Opción 1	-3.2	Opción 1	2 días	Opción 2	Opción 4	-3,-1,4			
16	09-Sep-2020	1826257e...	5	Hombre	Opción 1	Opción 1	3.2	Opción 4	2.5 días		Opción 3	3,-1,1	Opción 2		
17	09-Sep-2020	1826235h...	8	Hombre	Opción 1	Opción 2	-3.2	Opción 4	2 días	Opción 4	Opción 3	-3,1,2	Opción 2		
18	09-Sep-2020	1827068f...	4	Mujer	Opción 1	Opción 2	-3.2	Opción 4	2.5 días	Opción 2	Opción 1	-3,1,2	Opción 2		
19	09-Sep-2020	1826223x...	8	Hombre	Opción 1	Opción 2	2.3	Opción 4	2 días	Opción 4	Opción 3	-3,1,2	Opción 2		
20	09-Sep-2020	1835467e...	3	Hombre	Opción 1	Opción 4	3,-2	Opción 4	2.1 días	Opción 2	Opción 2	3,1,-4	Opción 4		
21	09-Sep-2020	1826357f...	8	Mujer	Opción 1	Opción 2	3,-2	Opción 4	2 días	Opción 1	Opción 3		Opción 2		
22	09-Sep-2020	1701350g...	5	Hombre	Opción 2		3.2	Opción 4	2 días	Opción 2		3,-1,1	Opción 2		

Fuente: Elaboración propia

Figura 5. Datos procesados en SPSS versión 25 del cuestionario referente a la categoría de aritmética.



	Puntaje	Sexo	Sumafraccc	Productfraccc	DivFracc	Raíz	Jerarquía	Potencias	Porcentaje	Probente	Fracc.impr	Log	Prob.f
1	9	Hombre	Opción 2	Opción 1	Opción 1	Opción 1	12	64	300	43.30	Opción 4	3	Opción 1
2	8	Hombre	Opción 2	Opción 1	Opción 2	Opción 1	2	64	300	387.21	Opción 2	2	Opción 1
3	6	Mujer	Opción 1	Opción 1	Opción 3	Opción 3	2	12	300	43.30	Opción 3	2	Opción 4
4	7	Hombre	Opción 2	Opción 1	Opción 2	Opción 1	12	64	300	43.30		2	Opción 4
5	10	Hombre	Opción 2	Opción 1	Opción 3	Opción 1	2	64	300	387.21	Opción 3	2	Opción 3
6	12	Mujer	Opción 2	Opción 1	Opción 1	Opción 1	12	64	300	252.29	Opción 4	2	Opción 2
7	11	Hombre	Opción 2	Opción 1	Opción 1	Opción 2	12	64	300	252.29	Opción 4	2	Opción 2
8	11	Mujer	Opción 2	Opción 1	Opción 1	Opción 1	2	64	300	252.29	Opción 4	3	Opción 2
9	6	Hombre	Opción 1	Opción 1	Opción 4	Opción 1	12	64	300		Opción 2	2	Opción 4
10	9	Hombre	Opción 2	Opción 1	Opción 3	Opción 1	2	64	300	43.30	Opción 3	2	Opción 3
11	12	Mujer	Opción 2	Opción 1	Opción 1	Opción 1	2	64	300	252.29	Opción 4	2	
12	10	Mujer	Opción 2	Opción 1	Opción 1	Opción 2	2	64	300	252.29	Opción 2	2	Opción 2
13	7	Hombre	Opción 1	Opción 1	Opción 4	Opción 1	2	12	300	252.29	Opción 2	2	Opción 4
14	4	Mujer	Opción 2	Opción 3	Opción 2	Opción 2	12	12	300	43.30	Opción 2	3	Opción 1
15	12	Hombre	Opción 2	Opción 1	Opción 1	Opción 1	12	64	300	252.29	Opción 4	2	Opción 2
16	10	Mujer	Opción 1	Opción 1	Opción 1	Opción 1	2	64	300	252.29	Opción 2	2	Opción 2
17	7	Hombre	Opción 2	Opción 1	Opción 3	Opción 1	12	64	300	43.30	Opción 2	2	Opción 3
18	11	Mujer	Opción 2	Opción 1	Opción 1	Opción 2	2	64	300	252.29	Opción 4	3	Opción 2
19	13	Mujer	Opción 2	Opción 1	Opción 1	Opción 1	2	64	300	252.29	Opción 4	2	Opción 2
20	13	Mujer	Opción 2	Opción 1	Opción 1	Opción 1	2	64	300	252.29	Opción 4	2	Opción 2

Fuente: Elaboración propia