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*Artículos científicos*

# Entorno virtual de aprendizaje y rendimiento académico de estudiantes de nivel superior en el tema de funciones matemáticas

## *Virtual Learning Environment and Academic Performance of Higher-Level Students in the Subject of Mathematical Functions*

## *Ambiente virtual de aprendizagem e desempenho acadêmico de alunos de nível superior na disciplina de funções matemáticas*

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## Resumen

El propósito del presente estudio fue determinar cómo influye el uso de un entorno virtual de aprendizaje (EVA) como complemento didáctico en el tema de funciones matemáticas en estudiantes de la Facultad de Ciencias Económicas Administrativas de la Universidad Autónoma del Carmen. Se siguió una metodología de tipo correlacional, con diseño cuasiexperimental, con pretest y postest. La muestra, no probabilística, fue de 125 estudiantes. Los resultados indican que hubo diferencias estadísticas significativas entre el nivel de desempeño cognitivo que alcanzaron los alumnos que utilizaron la plataforma y los que no lo usaron: quienes integraron los grupos experimentales se vieron favorecidos. Por lo tanto, existe un mejor desempeño cognitivo como consecuencia de una mayor participación de los estudiantes en el EVA. De igual manera, la didáctica en el aula virtual favoreció la autonomía y la autorregulación. Por último, la interacción de los participantes en el EVA incrementó su nivel de desempeño en los dominios cognitivos de conceptualización y operatividad, pese a que para el dominio de las habilidades de aplicación fue menor.

**Palabras clave:** desarrollo de habilidades matemáticas, entorno virtual de aprendizaje, estándares académicos, estudiantes universitarios, tecnología educacional.

## Abstract

The purpose of this study was to determine the influence of the use of a virtual learning environment (VLE) as a didactic complement in the subject of mathematical functions in students of the School of Economic and Administrative Sciences of the Universidad Autónoma del Carmen. A correlational methodology was followed, with a quasi-experimental design, pretest and post-test. The non-probabilistic sample consisted of 125 students. The results indicate that there were significant statistical differences between the level of cognitive performance achieved by students who used the platform and those who did not use it: those who integrated the experimental groups were favored. Therefore, there is a better cognitive performance because of greater student participation in the VLE. Similarly, didactics in the virtual classroom favored autonomy and self-regulation. Finally, the interaction of the participants in the VLE increased their level of performance in the cognitive domains of conceptualization and operability, although it was lower in the domain of application skills.

**Keywords:** mathematics skills development, virtual learning environment, academic standards, university students, educational technology.

## Resumo

O objetivo deste estudo foi determinar como o uso de um ambiente virtual de aprendizagem (EVA) influencia como complemento didático no assunto de funções matemáticas em alunos da Faculdade de Ciências Econômicas Administrativas da Universidade Autônoma de Carmen. Seguiu-se uma metodologia de tipo correlacional, com um desenho quase-experimental, com pré-teste e pós-teste. A amostra não probabilística foi de 125 alunos. Os resultados indicam que houve diferenças estatisticamente significativas entre o nível de desempenho cognitivo alcançado pelos alunos que usaram a plataforma e os que não a usaram: os que fizeram parte dos grupos experimentais foram favorecidos. Portanto, há um melhor desempenho cognitivo como consequência de uma maior participação dos alunos no EVA. Da mesma forma, a didática na sala de aula virtual favoreceu a autonomia e a autorregulação. Por fim, a interação dos participantes no EVA elevou seu nível de desempenho nos domínios cognitivos de conceituação e operacionalidade, apesar de ter sido menor no domínio de habilidades de aplicação.


**Palavras-chave:** desenvolvimento de habilidades matemáticas, ambiente virtual de aprendizagem, padrões acadêmicos, estudantes universitários, tecnologia educacional.

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# Introduction

The learning process of mathematics constitutes a challenge for teachers of higher education institutions (HEIs), since it is one of the areas where students at this level present the most difficulties. There are records that point to desertion as one of the problems presented by HEIs in Mexico, coupled with the failure of courses, lag, low performance and terminal efficiency, which are attributed to various causes related to the rigidity of educational programs, learning evaluation, learning methods or strategies, the inadequate role of the teacher, the lack of support programs for students, among others (López, 2020).

The Autonomous University of Carmen (Unacar), concerned with meeting the challenges and demands of society, has gone through various educational models in order to respond to educational trends and policies, as well as offer quality education. For this reason, through its Acalán Educational Model (Unacar, 2018), it seeks to generate new learning scenarios that launch a change in attitude of both the teacher and the student.

From the perspective of teaching work, new trends point towards the development of abilities, skills and attitudes in students through new learning scenarios mediated by technologies, with the purpose of facing the changes and transformations that are taking place around the knowledge and information society (García, Ortiz and Chávez, 2021). In this sense, the educational model centered on learning and with a focus on Unacar competencies positions the student as the central axis of the training action, therefore, as the person responsible for taking control of their own learning. At the same time, it encourages the teacher to adopt a new role, either as a learning facilitator or as a guide that accompanies the student during said process.

Undoubtedly, information and communication technologies (ICT) play an important role in educational models focused on learning, since the insertion of learning strategies or teaching support tools favor the development of abilities and skills in students. In this sense, in the field of teaching mathematics, the teacher can use different educational methodologies to achieve the desired performance of their students through the use of technology. Along this line, Sánchez (2000) establishes a link between the constructivist approach and mathematics education assisted by ICTs, pointing out that these can be used as: a) support tools for learning; b) means of construction that facilitate the integration of the known and the new; c) extenders and amplifiers of the mind; d) means that are transparent or invisible to users, and e) tools that participate in an orchestrated methodological set.

However, the insertion of technologies in the mathematics curriculum is necessary and valuable in a constantly changing society. Although it is important to consider that during the learning of mathematics there are various technologies, virtual learning environments (EVA) are ideal scenarios for the development of knowledge and skills of students. In addition, they can incorporate learning activities that respond to different learning styles, promoting the acquisition and development of knowledge in a flexible and autonomous way (Müller, Vranken, Engler, 2012).

One of the main objectives of the HEIs is to maintain high levels of school performance in their students, however, there are various causes that prevent these acceptable standards from being achieved. And precisely one of the difficulties encountered is the performance of students in courses related to the area of mathematics.

For this, academic performance is defined as:

> A value attributed to student achievement in academic tasks, and the way to verify said achievement, is with grades or grades, which allow the measurement and classification of students. It is important to highlight that student achievement in the use of academic activities depends on different internal and external factors. (Londoño y Villegas, 2017, p. 2).

Going back to the topic, HEIs in Mexico have registered problems related to low performance, failure and desertion in courses that have to do with math or science skills. For example, in an investigation carried out by Cú (2005) it was possible to identify, in 85 student records of the Autonomous University of Campeche, a failure rate of 30.56% and a dropout rate of 17.65%. On the other hand, the findings reveal that the possible causes of desertion, course failure, falling behind and low academic performance of students in the first semesters are: lack of vocational guidance on the choice of their careers, lack of motivation and low knowledge acquired. at the upper secondary level in some areas of mathematics, physics and chemistry.

For his part, Aparicio (2006) conducted a study at the Autonomous University of Yucatan, in the Faculty of Mathematics, where he was able to observe that only a third of the students who enter any of the six majors successfully complete their studies. According to the study, a high failure and dropout rate was identified in the courses of the first semesters; in addition, low graduation rates and performance in courses related to mathematics.

In the same southeastern part of the country, at the Universidad Veracruzana, Campus Coatzacoalcos, Gómez and Fernández (2009) carried out a descriptive and exploratory study in order to determine the level of previous knowledge that new students brought in three areas: mathematics , administration and accounting. To do this, 305 students from the 2008 period were surveyed. The results showed that university students lacked certain knowledge and skills in the mentioned areas when entering the higher level.

However, in the Unacar, IES where the present investigation is developed, different studies have been carried out with students from the first semesters of the different faculties of Engineering, Educational Sciences and Administrative Economic Sciences as a sample. The results have evidenced the low performance and failure of students in mathematics courses. This is what those found by Lagunes, López and Herrera (2009) do, who, when analyzing the performance of the students in the Mathematics I course, determined that 44% accredited the course on their first opportunity, 47% repeated the course and 8.8 % dropped out of course. In addition, they pointed out that the part of algebraic expressions and the solution of problems is what is most complicated for students. In addition to the above, there are very marked deficiencies in the students of the first semester with respect to mathematical skills, namely: assimilating the approach of a problem, making a proposal for steps to follow in solving problems and the operation of fundamental expressions, which represents the base for any higher level student (Zavaleta, Ayala and Pérez, 2009).

In a study carried out by the authors Díaz, Saucedo, Jiménez and Recio (2012) in the same IES, but taking the Faculty of Administrative Economic Sciences as a context, low performance was detected in mathematical skills on the subject of functions of the students of the second semester. These abilities have to do with the conceptualization and operation of the basic functions and, consequently, the low mastery of the previous abilities hinders the modeling and application of the functions. Along this line, Ruiz (2007) mentions that the aspects that are most difficult for students when addressing these topics related to calculation are solving exercises, setting up new problems and interpreting the results.

The subject of mathematical functions is found in the content of a differential calculus course. These types of courses are taught in educational programs of engineering and administrative economic sciences. For educational programs related to economic sciences, the calculus course represents a challenge for teachers, since the presence and didactics of some content that is intended for students to assimilate is not an easy task. (Armero, 2021).

For researchers in mathematics education, the subject of mathematical functions constitutes an inexhaustible object of study due to the learning difficulties that students present. According to García and Rivera (2009) and Flores and Chávez (2013), the existing difficulties in the subject of functions are: a) the construction and interpretation of graphs; b) understanding of the concept of function; c) handling of literals to represent numbers; d) dependency relationship between two variables, and e) problem solving. Due to the emergence of web technologies, today there is a wide variety of technological resources that can support the learning process of mathematics in HEIs. Such is the case with EVAs. An environment of this type is "an interactive computer program of a pedagogical nature that has integrated communication capacity, that is, it is associated with new technologies" (Silva, Morales and Esteban, 2010, p. 70).

For Chávez (2019), VLEs can be considered as didactic support tools capable of changing student behavior for the generation of their knowledge, since they favor the abilities to teach to think, find the optimal path and solve problems with instinct. On the other hand, Bautista (2008) mentions that virtual environments as support in the learning process provide significant learning, since these media tools allow interaction between: a) teacher-students, b) student-student, c) students- didactic materials presented in experiences, simulators, and didactic proposals with situations of daily life.

An EVA is understood as an educational space based on web tools that allows didactic interaction and the exchange of information between students and that enables the development of the learning process (United Nations Educational, Scientific and Cultural Organization [ Unesco], 1998; Salinas, 2011). Likewise, Ogalde and González (2008) define it as a computer tool used by students in conjunction with other means or didactic activities to achieve academic objectives. In addition, they are considered open, flexible and that they can be inserted into any learning process. Depending on the use that is given to them, they can be supported by various constructivist, behavioral or cognitive scenarios, which favor autonomous and collaborative learning.

Considering the references of the previous authors, the EVA can be understood as pedagogical spaces that respond to various modalities, and that integrate various pedagogical tools for communication and information exchange, which arouse the interest and motivation of the student towards the construction of their own knowledge. In addition, they allow them to reflect on their learning and, consequently, to self-regulate during the educational intervention (learning to learn). However, it is important to consider that the design and planning of the activities considered within the virtual environment must be consistent with the pedagogical approach of the curriculum.

Regarding the elements that constitute an EVA, Jaar (2021) raises the importance of virtual learning platforms as tools that favor the learning process, particularly at the higher level. Consequently, the teacher is considered responsible for the selection, sequence and structuring of the space to mediate the information through technological tools, so it must be even more participatory than in the face-to-face modality. For their part, students, as independent protagonists and motivated by digital resources, must carry out the activities planned by the teacher in order to promote their autonomous and collaborative learning through constructivist tasks.

In relation to its implementation, at the Faculty of Exact Sciences and Technologies of the National University of Santiago del Estero, Argentina, a didactic experience was carried out with a virtual learning environment (Moodle), which consisted of a series of practical teaching to achieve competencies. In this experience, a student-centered conceptual model was used for the development of higher order skills supported by a technological structure. Based on the results obtained, it is concluded that these learning environments improve the interaction between teacher-student, enhance the self-management skills of the student's knowledge, improve collaboration, exchange and communication interactivity and strengthen the results of the training action (Sosa, 2009).

For his part, Manjarrés (2010) carried out a study to visualize how an EVA as a complement to face-to-face classes affects the development of mathematical skills in students. In the investigative experience, both qualitative and quantitative analysis techniques were used that allowed a broader approach to the transformations that occurred in the mathematical skills of the students during the interaction with the EVA. Throughout this experience, students had access to the following sources: chats, forums, audios, oral exercises, written exercises, and evaluations or written tests. According to the results obtained, there was an increase in the active participation of the students. Also, a 20% increase in the correct use of mathematical symbols in students' written tests. However, the students presented a 10% decrease in their ability to write, focused on the coherence of the discourse.

At the Escuela Superior de Ingeniería Mecánica y Eléctrica Zacatenco del Instituto Politécnico Nacional, García and Benítez (2011) carried out a work that aimed to document and analyze the types of reasoning that students undertake when solving mathematics problems and interacting with an EVA ( specifically in Moodle). The methodology used was qualitative; a didactic sequence consisting of eight activities was designed. In the design of the activities, two main variables were considered: the underlying mathematical content of the activity and the mathematical skills related to the use of technology that students are expected to develop. The results showed that the students had no problem using Moodle. However, it was possible to appreciate that collaborative interaction does not occur spontaneously and must be part of the teacher's agenda.

Similarly, in a study carried out at the higher level by Maz, Bracho, Jiménez and Adaluz (2012) on the use of Moodle in the subject of mathematics, it was possible to observe the participation of the students through the discussion forums. The results obtained showed that through the virtual forum, cooperative work skills, autonomous learning, leadership and critical judgment in students can be fostered, as well as the identification of their deficiencies in understanding the concepts addressed. On the other hand, the authors point out that this virtual tool would be more useful in advanced mathematics courses if it is decided to work with these resources from the first courses.

Likewise, Albano (2012) points out that an EVA is of great importance since, if it is properly designed, students can develop mathematical knowledge and skills. In addition, this type of technology-based environment favors the diversity of student learning methods and the automatic monitoring of both individual and group learning. This allows students to vary their attitude regarding the learning of mathematics that leads to the improvement of their performance in mathematics courses.

Regarding the EVA as a didactic complement in learning mathematics, Müller et al. (2012) propose learning activities in an environment of this type on the subject of mathematical functions for students who presented learning difficulties. For this, an educational scenario was designed and implemented in Moodle combining virtual and face-to-face activities. The activities were varied and with different degrees of complexity and abounded in content in order to enrich their possibilities and promote reflection on what was learned. The virtual activities were activity resolution guides, reflection forums and self-assessment questionnaires. The results showed that as the weeks progressed, the participation of the students in most of the activities decreased. Although the students showed deficiencies when giving their opinion in the discussion forums, since they lacked the conceptualization, symbology and operability of the functions.

The researchers Piña and Torrealba (2020) also proposed an EVA as a valid didactic strategy for the administration of the curricular units. Their results show that ICTs in HEIs offer innovation in educational practices, which are strengthened through VLEs as support for traditional teaching from interactivity, communication, dynamism in the presentation of content, and different learning styles. This favors students to assume and demonstrate their personal and professional skills through self-learning and self-regulation.

For his part, Bonilla (2021) implemented an EVA as a strategy to strengthen mathematical skills in 10th grade students within the comprehensive secondary education project of the Misael Pastrana Borrero School. There, the need to integrate ICTs to promote the blended learning modality is raised. The research was developed in an interpretive paradigm, with a mixed approach, using a diagnostic test to identify the level of mathematical knowledge, which was analyzed quantitatively. Subsequently, the connectivity of students and teachers was analyzed through interviews and finally an EVA was designed and implemented, evaluated based on the perception and experience of the students.

## Materials and methods

According to Hernández, Fernández and Baptista (2018), this work is quantitative-correlational, since it allows showing the level of relationship between two or more variables. This approach allowed us to determine the effect of EVA (Moodle) as a didactic complement on the academic performance of mathematical functions in students of the course "Development of mathematical thinking for companies" of the Faculty of Administrative Economic Sciences of Unacar. The objective of the study was to analyze how the use of an EVA as a didactic complement influences the academic performance of the students of the aforementioned course, specifically in the subject of mathematical functions. That is why the choice of this type of research is correlational, since it sought to respond to the following hypotheses:

- $H_1$: Including an EVA (Moodle) as a didactic complement to the course "Development of mathematical thinking for companies" influences the academic performance of students in the subject of mathematical functions.
- $H_2$: There is a difference in the level of cognitive performance of the students in the course "Development of mathematical thinking for companies" who used an EVA (Moodle) as didactic support in the subject of functions with respect to those who did not use it.
- $H_3$: The higher the performance obtained by the students in the learning activities proposed in the EVA (Moodle), the higher the performance in the post-test of mathematical functions.

To respond to the hypotheses, a quasi-experimental design with pretest and posttest was carried out. One of the reasons why the quasi-experimental design was chosen is because it allows working with intact groups or in natural conditions according to the formation of the groups in higher level educational institutions.

Undoubtedly, it must be recognized that one of the disadvantages of the quasi-experimental design is the absence of randomness, this implies the presence of possible problems of both internal and external validity. However, it can provide clear evidence of the effects of one variable on another for a given population or sample.

The structure of the quasi-experimental design with intact groups (experimental group and control group) implies the use of pretest-posttest. Table 1 shows the diagram associated with the quasi-experimental design of the research.

**Table 1.** Quasi-experimental design with intact groups

| | | | |
|---|---|---|---|
| GE | $O_1$ | X | $O_2$ |
| GC | $O_1$ | - | $O_2$ |

Note: GE = Experimental group, CG = Control group, O1 = Pretest of the theme of functions, O2 = Posttest of the theme of functions, X = Treatment (normal class + didactic support in Moodle), - = Without treatment (normal class, without the use of EVA)

Source: self made

With this design, information was collected to test the working hypotheses and to be able to determine the effect of the EVA (Moodle) as a didactic complement on the academic performance of mathematical functions in the students of the course

"Development of mathematical thinking for companies" of the Faculty of Administrative Economic Sciences.

## Population and sample

The course "Development of mathematical thinking for companies" is part of the interdisciplinary skills of the Socioeconomic Administrative area. For this reason, the course is considered as a common core subject in the Faculty of Administrative Economic Sciences of Unacar. Consequently, all students enrolled in the different educational programs of the faculty must take it in the first semesters of their degree. In addition, it is a serial course for the subjects of "Applied Statistics for Businesses I", "Applied Statistics for Businesses II" and "Financial Mathematics". The population of students who attended said course were 186 students distributed in six groups, of which 123 were female and 63 male.

Because a quasi-experimental design was used in the research, intact groups of students enrolled in the course "Development of mathematical thinking for companies" were taken. For the selection of the experimental and control groups, four groups were chosen, two for the experimental group and two for the control group, with the intention of considering the largest possible number of cases. The sample was not probabilistic, since the groups were not randomly formed, but were organized according to the schedules, and cannot be changed. Therefore, the groups were chosen intentionally taking care that the teacher who participated in the study taught at least four groups. Consequently, only one teacher participated, since he was the only one who had at least four groups.

The sample consisted of 125 students divided into two experimental groups and two control groups. The ages of the students vary between 18 and 30 years. In addition, there was participation of both genders (women and men).

Table 2 shows the distribution of students in the experimental and control groups.

**Table 2.** Sample Distribution

| Grade | Group | Time | Women | Man | Total Students |
|---|---|---|---|---|---|
| 2.° | Experimental | 7:00-9:00 h | 19 | 12 | 31 |
| 2.º | Control | 7:00-9:00 h | 18 | 10 | 35 |
| 2.° | Experimental | 9:00-11:00 h | 24 | 10 | 34 |
| 2.º | Control | 13:00-15:00 h | 21 | 11 | 32 |
| Total | 6 | 4 | 82 | 43 | 125 |

Note: data taken from the official lists of the participating teacher.

Source: self made

## Instruments

In this research, there are two instruments (pretest and posttest) in order to measure the dependent variable and answer the research question.

The pretest instrument is a diagnostic test that contemplates the content of functions of the first learning sequence, in which indicators (which are specific capacities of the subject of functions) and the dimensions that refer to the cognitive domain are identified. To integrate this test, a series of items were elaborated and integrated with the purpose of measuring the level of cognitive performance in the subject of functions of the students of the mentioned course. The pretest was made up of cognitive dimensions or domains as shown in Table 3, which made it possible to group the specific cognitive abilities of the subject of mathematical functions of the course in question.

**Table 3.** Dimension or cognitive domains in the subject of functions

| Cognitive domains | Definition |
|---|---|
| Conceptualización | As part of this dimension, the student must know the type of general information addressed in the mathematical problems and tasks on the subject of functions, and can contemplate relationships, graphs, quantity, and shape. |
| Operability | In this dimension, the student must show a series of capacities that have to do with the reproduction of calculations and procedures on the subject of functions, the connection established by the representation of a problem through different representations, and the reflection that has to do with with the explanation and interpretation of phenomena from various areas of knowledge. |
| Application | Here the student must be able to solve mathematical problems from various contexts (personal, public, educational or work and scientific), and in particular the solution of problems that involve functional mathematical models of daily life and the economic-administrative area. |

Information: prepared by the researcher

The pretest instrument was made up of 22 dichotomous items distributed in three cognitive domains, which are associated with a series of indicators consistent with the content addressed that will allow measuring the cognitive performance of the students in the course.

Next, Table 4 shows the distribution of the items grouped into three dimensions or cognitive domain of analysis.

**Table 4**. Distribution of items by cognitive competence of the Pre-test

| Content of functions | Cognitive competence | Ítems |
|---|---|---|
| *1)* Concept of functions from an algebraic, graphical and numerical point of view (46 %)<br><br>*2)* Functions from a graphical point of view. Linear, quadratic, exponential and logarithmic models (27 %)<br><br>*3)* Application and interpretation of results (27 %) | Conceptualization | Example question:<br>Item 3. What is the maximum number of roots that a function can have?<br><br>Justify your answer:<br><br>Answer Options:<br>a) 0 b) 1 c) 6 d)7<br><br>Competition Items:<br>1, 2, 3, 4, 5, 6, 7, 8, 9, 10 |
| | Operability | Example question:<br>Item 11. A manufacturer has fixed monthly costs of \$80,000 and a unit production cost of \$25. The product sells for \$35 per unit. The profit function is?<br><br>Approach:<br><br>Answer Options:<br>$a) U(x) = -10x - 80{,}000$<br>$b) U(x) = 10x + 80{,}000$<br>$c) U(x) = 10x - 80{,}000$<br>$d) U(x) = -79{,}990$<br><br>Competition Items:<br>11, 12, 13, 14, 15, 16 |

| | | |
|---|---|---|
| | Application | Example question:<br>Item 19. A video rental store charges a membership fee of \$100 plus \$40 for each movie rental. What is the model that represents the total cost C of x rentals?<br><br>Approach:<br><br>Answer Options:<br>$a) C(x) = 100x + 40$<br>$b) C(x) = -100x + 40$<br>$c) C(x) = 40x - 100$<br>$d) C(x) = 40x + 100$<br><br>Competition Ítems:<br>17, 18, 19, 20, 21, 22 |

Information: prepared by the researcher

Having the final instrument (pretest), its validity and the reliability calculation were confirmed. It should be specified that validity refers to whether the instrument measures what it should measure, and in terms of reliability it refers to the consistency of the results and the degree of consistency of an instrument (Bisquerra, 2000; Hernández et al., 2018). There was a critical evaluation of two experts in the subject of mathematical functions, since there is no standardized instrument to measure the level of cognitive performance in the subject of functions.

To measure the internal reliability of the test scores, the procedure used was the Kuder-Richardson 20 formula. This process is applicable to dichotomous item tests in which there are correct and incorrect answers. The pretest was applied to a group of 24 students with similar characteristics to the groups selected in the study. The Kuder-Richardson 20 test was applied to the results obtained from the test, from which a reliability coefficient of 0.8917 was obtained, which according to the authors Ortiz and Noriega (2007), in the case of a non-standardized test, a coefficient greater than 0.70 shows a very adequate level of reliability. The second instrument (posttest) was an objective test with the same characteristics and number of items equivalent to the pretest in order to compare the cognitive performance achieved by the students before and after the treatment.

It should be noted that in order to assess the results, it is necessary to know what the students know and how to do, since the higher the student's score in a subject, the more tasks they can satisfactorily solve (Leyva, Proenza and Romero, 2008).

Based on the above, the research makes a classification to measure the level of performance by cognitive domain (see table 5).

**Table 5**. Performance levels by cognitive competence

| Niveles de desempeño | Percentage of success in each cognitive competence |
|---|---|
| Insufficient (1) | Fewer or same than 40 % |
| Deficient (2) | More than 40 % and fewer or same than 50 % |
| Basic (3) | More than 50% and fewer or same than 60 % |
| Medium (4) | More than 60 % and fewer than 80 % |
| High (5) | More or same than 80 % |

Information: prepared by the researcher

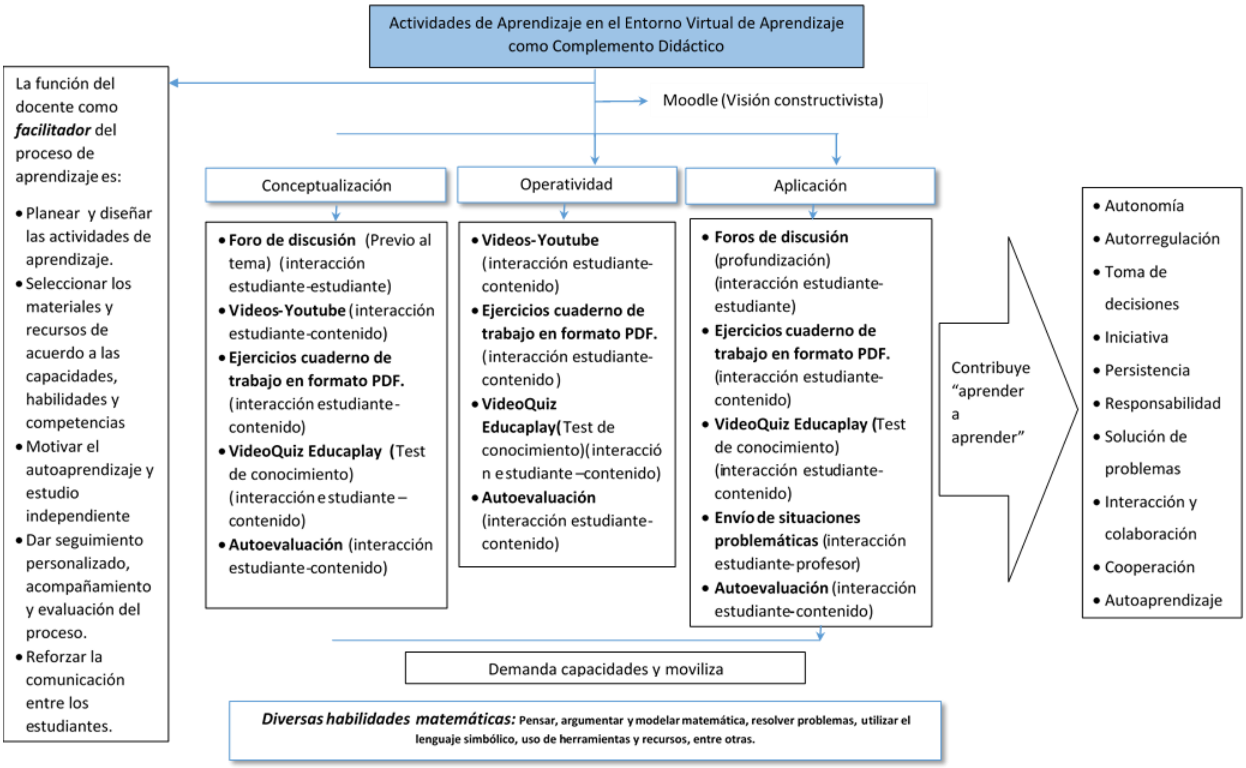
## Didactic proposal

The methodology used is based on strategies to develop the autonomy and self-regulation of the students through the learning activities proposed in the EVA. These learning activities are typical of mixed teaching; they complement face-to-face classes with permanent work on the virtual platform and respect the times planned in the first learning sequence of the face-to-face course. Taking into account that mathematics is a discipline with a high level of abstraction, it was proposed to stimulate the learning of each specific topic through the tools that the educational platform integrates. With the use of Moodle, the aim is to transform the classroom into a learning community involving students in tasks or learning activities with different cognitive levels (conceptualization, operability and application); At the same time, it demands specific skills that allow one to argue, think and communicate mathematically, solve problems and use tools on the subject of mathematical functions. Therefore, what is planned in the virtual platform must be understood as a didactic support or complement to the face-to-face course, similar to the blended model approaches.

On the other hand, the planning of learning activities with the support of the Moodle platform not only has the purpose of developing the cognitive abilities of the students in the subject of mathematical functions, but through the same subject other skills are developed. such as autonomy, self-regulation, decision-making, initiative, persistence, responsibility, problem solving, interaction and collaboration, cooperation, self-learning, among others. These skills are necessary for the comprehensive training of students and for their professional life.

Below is an outline of the learning activities with the use of the Moodle platform tools as a didactic complement to the subject of mathematical functions of the face-to-face course "Development of mathematical thinking for companies".

**Figure 1.** Scheme of the learning activities proposed in the EVA




Information: prepared by the researcher

Figure 1 shows that the activities in the Moodle platform support the development of the cognitive domain (conceptualization, operation and application) of the subject of mathematical functions. Through them, the aim is to promote and develop in students autonomy, motivation, responsibility, decision-making and self-regulation during their learning process. In this sense, the way in which cognitive activities or tasks are structured is of great importance, since they must satisfy the cognitive, autonomy and socio-affective needs of students with the purpose of encouraging their autonomous and self-regulated learning.

# Results

To determine if the inclusion of an EVA (Moodle) as a didactic complement in the course "Development of mathematical thinking for companies" influences the academic performance of students in the subject of functions, we proceeded to carry out the analysis and interpretation of information.

To test the homogeneity between the groups before treatment, an analysis of variance (Anova) of one factor or fixed effects pathway was used, thanks to which it was shown that there is no difference between the means (see table 6).

**Table 6.** Test of homogeneity between groups through the statistic Anova

| | Sum of quadrate | *Gl* | Average quadratic | *F* | Sig. |
|---|---|---|---|---|---|
| Between groups | 0.517 | 3 | 0.172 | 0.701 | 0.553 |
| Inside the groups | 29.755 | 121 | 0.246 | | |
| Total | 30.272 | 124 | | | |

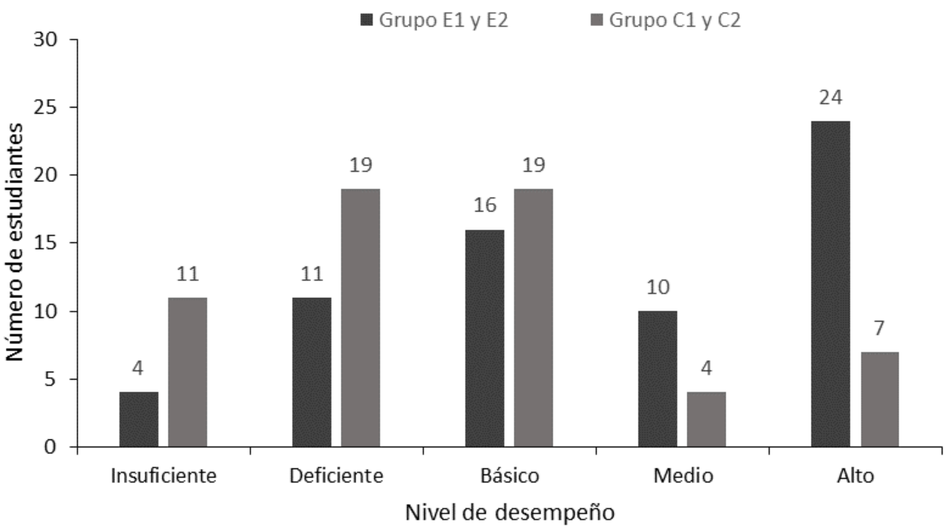
Note: results of the Anova test of the pretest in the IBM SPSS program

Source: self made

Since the p-value of the F test is greater than 0.05 (0.071 > 0.05), it means that there is no statistically significant difference between the means of the two variables at 95% confidence. Therefore, there is no significant statistical difference between the means of the level of cognitive performance reached in the pretest of mathematical functions by the students of the course "Development of mathematical thinking for companies" of the experimental and control groups. In other words, the experimental and control groups are in the same cognitive conditions before starting the treatment.

To respond to hypothesis H2, "There is a difference in the level of cognitive performance of the students in the 'Development of mathematical thinking for companies' course who used an EVA (Moodle) as didactic support on the subject of functions, with with respect to those who did not use it”, the descriptive analysis of the level of performance was carried out, by cognitive domain, in the subject of functions. Next, the post-test analysis of the experimental (E1 and E2) and control (C1 and C2) groups is presented.

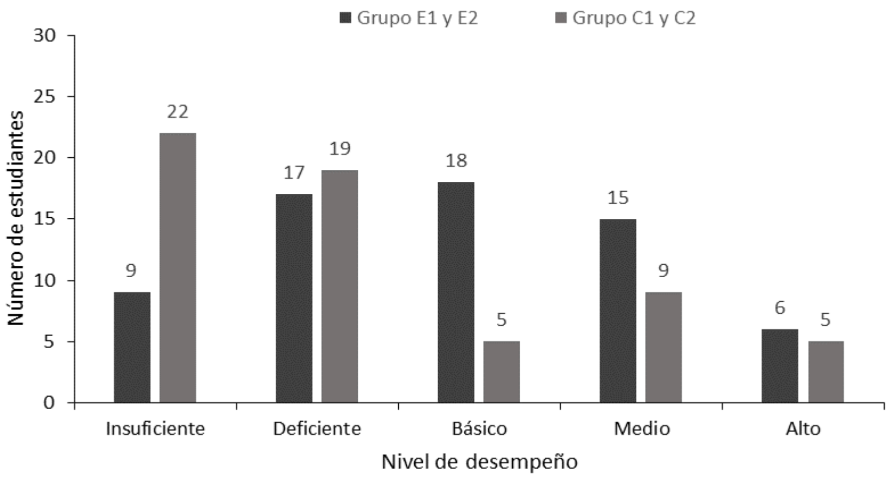
**Figure 2**. Level of performance of the conceptual competence of the experimental and control groups




Information: prepared by the researcher

It is observed in figure 2 that the experimental and control groups have a different level of conceptual performance. In addition, it can be seen that most of the students of the experimental group are located in the basic, medium and high level; while in the control group most of the students are in the insufficient, deficient and basic level.

**Figure 3**. Performance level of procedural competence of the experimental and control groups




Information: prepared by the researcher

The experimental and control groups have a different level of procedural performance, since, as shown in figure 3, most of the students in the experimental group are located at the basic, medium and high level; while in the control group most of the students have an insufficient and deficient level.

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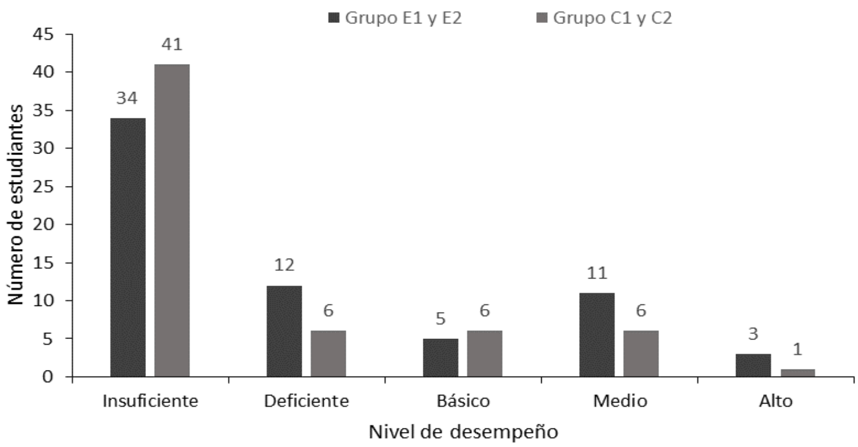
**Figure 4**. Performance level of the application competence of the experimental and control groups




Information: prepared by the researcher

The experimental and control groups have a slightly different level of cognitive application performance, since, as shown in Figure 4, the students of the experimental and control groups are distributed in the different levels in almost the same proportion. As can be seen, the majority of the study participants are in the insufficient and deficient levels, this implies that the students have problems in developing this cognitive domain.

**Table 6**. Hypothesis test between groups through the statistic Anova

| | Sum of quadrate | *Gl* | Average quadratic | *F* | Sig. |
|---|---|---|---|---|---|
| Between groups | 24.328 | 3 | 8.109 | 7.910 | .000 |
| Inside the groups | 124.040 | 121 | 1.025 | | |
| Total | 148.368 | 124 | | | |

Note: results of the Anova test of the posttest in the IBM SPSS program

Source: self made

As shown in table 6, the Anova breaks down the variance of the data into two components: a component between groups and a component within the groups, with an α of 5% significance. Since the p-value of the F test is greater than 0.05 (0.000 < 0.05), it means that there is a statistically significant difference between the means of the two variables at 95% confidence. Therefore, there is a significant statistical difference between the means of the level of cognitive performance reached by the students in the post-test of mathematical functions of the specified course. In other words, the experimental and control groups have different levels of cognitive performance in the subject of student functions: the students of the experimental groups stand out.

## Hypothesis testing

It is highly relevant to point out that the null hypothesis (H0), "There is no difference in the level of cognitive performance of the students in the 'Development of mathematical thinking for companies' course who used an EVA (Moodle) as didactic support in the issue of functions, with respect to those who did not use it", was rejected; and consequently, the research hypothesis H2, "There is a difference in the level of cognitive performance of the students in the 'Development of mathematical thinking for companies' course who used an EVA (Moodle) as didactic support on the subject of functions with respect to those who did not use it", was accepted.

## Relationship between performance in the virtual classroom and level of performance in the post-test

In order to respond to hypothesis H3, "The higher the performance obtained by the students in the learning activities proposed in the EVA (Moodle), the higher the performance in the post-test of functions", a descriptive analysis and the Pearson correlation between the performances were carried out. of the learning activities on the platform and the results of the students' post-test.

The activities that had more student participation are those related to the cognitive level of conceptualization.

**Table 7**. Correlations between students' competence in conceptualization activities in the virtual classroom and the level of conceptualization cognitive competence in the post-test

| | | EVA conceptualization | Post-test competition |
|---|---|---|---|
| EVA conceptualization | Pearson correlation<br>Sig. (bilateral)<br>N | 1<br><br>65 | 0.592**<br>0.000<br>65 |
| Post-test competition | Pearson correlation<br>Sig. (bilateral)<br>N | 0.596**<br>0.000<br>65 | 1<br><br>65 |

** The correlation is significant at the 0.01 level (2 tails).

Source: self made

Table 7 shows that the correlation of each variable with itself is perfect (the linear correlation coefficient is 1.0); while the correlation with another variable is 0.596. The positive value means that performance at the cognitive level of conceptualization increases as their performance in operational activities on the VAS increases, and this value translates into a moderate correlation between both variables. In the same way, the value of $p = 0.000 < 0.01$ means that the variables are linearly related, and it is interpreted that if the performance of students' conceptualization activities on the platform increases, their performance on the cognitive level of conceptualization on the platform increases. the posttest.

**Table 8**. Correlaciones entre el desempeño de los estudiantes en las actividades de operatividad en el aula virtual y el nivel de desempeño cognitivo de operatividad en el postest

| | | EVA operability | Post-test competition |
|---|---|---|---|
| EVA operability | Pearson correlation<br>Sig. (bilateral)<br>N | 1<br><br>65 | 0.610**<br>0.000<br>65 |
| Post-test competition | Pearson correlation<br>Sig. (bilateral)<br>N | 0.610**<br>0.000<br>65 | 1<br><br>65 |

** The correlation is significant at the 0.01 level.

Source: self made

Table 8 shows that the correlation of each variable with itself is perfect (the linear correlation coefficient is 1.0); while the correlation with another variable is 0.610. The positive value means that the performance in the operational cognitive level increases as their performance in the operational activities in the EVA increases, and this value translates into a moderate correlation between both variables. In addition, the value of p = 0.000 < 0.01 means that the variables are linearly related, and it is interpreted that if the performance of the students' operability activities on the platform increases, their performance in the cognitive level of operability increases in the post-test.

**Table 9**. Correlations between the performance of the students in the application activities in the virtual classroom and the level of application cognitive performance in the post-test

| | | EVA operability | Post-test competition |
|---|---|---|---|
| EVA operability | Pearson correlation<br>Sig. (bilateral)<br>N | 1<br><br>65 | 0.743**<br>0.000<br>65 |
| Post-test competition | Pearson correlation<br>Sig. (bilateral)<br>N | 0.743**<br>0.000<br>65 | 1<br><br>65 |

** The correlation is significant at the 0.01 level.

Source: self made

Table 9 shows that the correlation of each variable with itself is perfect (the linear correlation coefficient is 1.0); while the correlation with another variable is 0.743. The positive value means that performance at the application cognitive level increases as their performance in the application activities on the VAS increases, and this value translates into a moderate correlation between both variables. Likewise, the value of p = 0.000 < 0.01 means that the variables are linearly related, and it is interpreted that if the performance in the application activities of the students on the platform increases, their performance in the cognitive level of application in the post-test increases.

**Table 10**. Correlations between performance in the virtual classroom and the level of performance in the post-test

| | | EVA operability | Post-test competition |
|---|---|---|---|
| EVA operability | Pearson correlation Sig. (bilateral)<br>N | 1<br><br>65 | 0.685**<br>0.000<br>65 |
| Post-test competition | Pearson correlation<br>Sig. (bilateral)<br>N | 0.685**<br>0.000<br>65 | 1<br><br>65 |

*Note: **. The correlation is significant at the 0.01 level*

*Source: self made*

Similarly, in table 10 it can be seen that the correlation of each variable with itself is perfect (the linear correlation coefficient is 1.0); while the correlation with another variable is 0.685. The positive value means that the performance at the cognitive level in the post-test increases as their performance in the activities in the VAS increases, and this value translates into a moderate correlation between both variables. Likewise, the value of $p = 0.000 < 0.01$ means that the variables are linearly related, therefore, the null hypothesis (H0) is rejected and the alternative hypothesis (H3: "The higher the performance obtained by the students in the activities of learning proposed in the EVA (Moodle), better performance in the functions post-test").

In summary, to test the general research hypothesis (H1: "Including an EVA (Moodle) as a didactic complement to the mathematical thinking course for companies influences the academic performance of students in the subject of mathematical functions":

*1)* From the point of view of the level of cognitive performance, the hypothesis "There is a difference in the level of cognitive performance of the students in the course 'Development of mathematical thinking for companies' who used an EVA (Moodle) as support" was tested. didactic on the subject of functions with respect to those who did not use it", at a significance level of 0.05, acceptable for social research. The acceptance of the hypothesis proves that the students who interacted in the EVA had an improvement in their level of performance with respect to those who did not use it.

*2)* The insertion of the EVA as a didactic complement has an impact on the cognitive development of students in the subject of mathematical functions. And this relationship can be seen reflected in the accepted hypothesis "The higher the performance obtained by the students in the learning activities proposed in the EVA (Moodle), the higher the performance in the post-test of functions". The foregoing highlights the effects of the use of EVAs.

## Discussion

The use of EVA as a didactic complement. Once the statistics on the design and implementation of cognitive activities in Moodle as a complementary tool in the subject of mathematical functions were carried out, it was possible to verify that said didactic proposal allows to increase the level of performance of the students in their face-to-face course. These results coincide with the studies carried out by Jaar (2021), Manjarrés (2010) and Müller et al. (2012), where emphasis is placed on the improvement that students have in terms of their performance in courses where the use of EVA is implemented, this indicates that the insertion of platforms as support for the face-to-face course has a favorable impact on the development of students' cognitive abilities in mathematics at a higher level. In particular, working on the Moodle platform allows to enhance and innovate the mathematics learning process.

With the implementation of the didactic proposal, the autonomy and self-regulation of the study participants was promoted through self-assessment activities and discussion forums, these skills were reflected in the percentages of student participation in the learning activities proposed in the virtual classroom. Regarding the active participation of students in learning activities on the platform, these results differ from those obtained by Müller et al. (2012), since 100% of the student participation in all the activities was not recorded, but it coincides with the results obtained by the authors Mena, Golbach, Abraham and López (2014), in whose work you can see the positive relationship between performance in learning activities in the virtual classroom and the academic performance of students in the face-to-face mathematics course.

The implementation of learning activities in a VLE by themselves do not generate cognitive processes, but rather requires the commitment of the teacher in planning, reflection and improvement of these activities in their implementation, which implies new roles for teachers and students, as and as demanded by the new approaches supported by technologies. These activities implemented in the virtual classroom helped to increase the cognitive performance of the students of the experimental group. This coincides with the authors Müller et al. (2012) and Piña and Torrealba (2020) when they state that the implementation of learning activities in a virtual classroom enriches face-to-face sessions and represents an efficient didactic assistant for the teacher inside and outside the classroom. In addition, through the educational platform, the teacher may be able to encourage participation, collaboration and evaluation of the activities and fulfill the role of facilitator and companion of the learning process.

Based on the statistical results and the theoretical support of authors such as Piña and Torrealba (2020) and Armero (2021) and Jaar (2021), in the investigation it was possible to verify that the didactic planning of a mathematics course supported by an EVA helped the student to have control of his own learning process and allowed him to learn new techniques of communication, self-learning and interaction that strengthened his cognitive development. Of course, the success of EVA-based experiences depends on the didactic planning made by the teacher and the level of autonomy that the student can achieve in said experiences.

## Conclusions

Regarding the cognitive development of the students in the subject of mathematical functions, it was possible to statistically demonstrate that those with greater interaction in the EVA had better performance in the post-test. At a significance level of 0.05%, it was confirmed that the use of a VAS as a didactic complement improves cognitive performance and contributes to the autonomy of the participants. The didactic proposal in the virtual classroom through the activities allows the student to know his progress during the training process, know his mistakes and advance at his own pace. But, in addition, during the experience in the virtual classroom, she must be clear about her role as the person responsible for her own learning and must assume commitments during it. The teacher's task, on the other hand, should be to guide the training process, should motivate and stimulate the student's work during the didactic intervention.

In the investigation it was possible to show that the students who participated in the learning activities in the virtual classroom with responsibility obtained better results in the post-test of mathematical functions. This means that the learning activities and materials used in the platform were congruent with the objectives and competencies of the course. Consequently, there is a relationship between the performance of the students in the virtual classroom and their performance in the post-test, so the student who obtained the highest performance in their activities on the platform had a better performance in the functions post-test.

Regarding the cognitive performance obtained by the study participants during the didactic experience, it was observed that those who interacted with the virtual environment significantly increased their level in the cognitive domains of conceptualization and operability. Although it was lower for the domain of application, the results showed that the use of the virtual classroom as support for the face-to-face mathematics course enhances the level of student performance in cognitive tests and, consequently, favors the academic performance of students.

In the research, the primacy towards the development of cognitive processes (conceptualization, operability and application) can be seen, as well as in the skills that are developed in each one of them. In accordance with the above, the capabilities of the subject of functions were grouped into cognitive domains, which impact on various mathematical abilities. This means that the student who makes use of a capacity not only develops one competence, but more than one can be developed: a) the tasks referring to the cognitive domain of conceptualization demand certain capacities that allow the development of specific mathematical thinking skills , model, represent and use symbolic language; b) the tasks referring to the cognitive domain of operability, through the use of their capacities, allow the development of skills such as thinking, modeling, posing and solving problems, representing, using symbolic language, tools and resources; c) the tasks referring to the cognitive domain of application demand the application of certain capacities that develop the abilities of thinking, reasoning, arguing, communicating, modeling, solving problems, representing, using symbolic language, use of tools and resources.

Although the participation of the students in the virtual classroom is taken into account in their final grade, in the results obtained from their interventions it was possible to observe that a little more motivation is required to register 100% participation in all learning activities. . That is why the teacher must design and use tools that motivate and promote the autonomous-collaborative learning of mathematics.

According to the results obtained from the research, the use of an EVA as a didactic complement influenced the development of mathematical skills of the students of the course "Development of mathematical thinking for companies," in the subject of mathematical functions. The insertion of this type of didactic experiences in the planning of face-to-face courses is intended to respond to the demands of HEIs on strategic points such as: the use of technologies inside and outside the classroom, generating new learning scenarios and using new channels. communication tools that promote student-centered learning. In addition, the didactic experience with the use of technologies was enriching for the integral formation of the student, since it promoted cooperation and collaboration in the EVA, facilitating the development of cognitive abilities of the students and their change of attitude towards the learning process of mathematics.

## Future lines of research

For future research related to the topic, variables related to the teacher and connection time, among others, can be included. But for the implemented methodology to have a greater probability of success, it is important that the analysis of the management of educational platforms that teachers and students have is approached with a scientific approach. In the same way, the training of teachers on the design and management of VLEs with variables related to the design of learning activities by the teacher taking into account the needs of the students and the achievement of the objectives is proposed as a line of research. expected competencies. Another area of opportunity identified is the intrinsic motivation that students present to undertake their training in EVA. Likewise, more interactive activities should be considered at the cognitive application level, which refers to the solution of application problems of mathematical functions.

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