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Artículos científicos

Influencia de entornos virtuales de aprendizaje en el desarrollo de habilidades cognitivas: un modelo de ecuaciones estructurales

Influence of Virtual learning environments in the Development of Cognitive Abilities: A Model of Structural Equations

Influência de ambientes virtuais de aprendizagem aprendizagem no desenvolvimento de habilidades cognitivas: um modelo de equações estruturais

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Resumen

Los entornos virtuales de aprendizaje se han convertido en pieza esencial para configurar el nuevo perfil educativo México y en todo el orbe. El objetivo de esta investigación es identificar la influencia de los ambientes virtuales de aprendizaje en el desarrollo de habilidades cognitivas en hombres y mujeres mediante un modelo de ecuaciones estructurales. El método de investigación es cuantitativo y combina el enfoque descriptivo y correlacional. Se realizó un análisis factorial exploratorio, un análisis factorial confirmatorio y un modelo de ecuaciones estructurales. La muestra estuvo compuesta por 423 alumnos y alumnas de la Facultad de Contaduría y Administración de la Universidad Autónoma de Baja California. En los resultados se observa una incidencia positiva de los entornos virtuales para desarrollar habilidades cognitivas en estudiantes universitarios. En cuanto al género, es casi inapreciable la diferencia estadística entre unas y otros, ya que los indicadores para mujeres universitarias se muestran muy similares respecto al de los hombres, por lo que se infiere que el sexo no representa una diferencia significativa para el desarrollo de habilidades cognitivas dentro de un entorno virtual de aprendizaje.

Palabras clave: ecuaciones estructurales, entornos virtuales de aprendizaje, habilidades cognitivas.

Abstract

Virtual learning environments have become an essential piece in shaping the new educational profile in Mexico and around the world. The objective of this research is to identify the influence of virtual learning environments on the development of cognitive skills in men and women through a structural equation model. The research method is quantitative and combines a descriptive and correlational approach. An exploratory factor analysis, a confirmatory factor analysis and a structural equation model were performed. The sample consisted of 423 students from the School of Accounting and Administration of the Universidad Autónoma de Baja California. The results show a positive incidence of virtual environments to develop cognitive skills in university students. Regarding gender, the statistical difference between one and the other is almost negligible, since the indicators for female university students are very similar to those for male university students, so it can be inferred that gender does not represent a significant difference for the development of cognitive skills within a virtual learning environment.

Keywords: cognitive skills, structural equation, virtual learning environment.

Resumo

Os ambientes virtuais de aprendizagem tornaram-se uma peça essencial para configurar o novo perfil educacional no México e no mundo. O objetivo desta pesquisa é identificar a influência de ambientes virtuais de aprendizagem no desenvolvimento de habilidades cognitivas em homens e mulheres usando um modelo de equação estrutural. O método de pesquisa é quantitativo e combina a abordagem descritiva e correlacional. Análise fatorial exploratória, análise fatorial confirmatória e modelagem de equações estruturais foram realizadas. A amostra foi composta por 423 alunos da Faculdade de Contabilidade e Administração da Universidade Autônoma de Baja California. Os resultados mostram uma incidência positiva de ambientes virtuais para desenvolver habilidades cognitivas em estudantes universitários. Em relação ao sexo, a diferença estatística entre um e outro é quase insignificante, pois os indicadores para as mulheres universitárias são muito semelhantes aos dos homens, então pode-se inferir que o gênero não representa uma diferença significativa para o desenvolvimento de habilidades cognitivas dentro de uma ambiente virtual de aprendizagem.

Palavras-chave: equações estruturais, ambientes virtuais de aprendizagem, habilidades cognitivas.

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Introduction

The knowledge society demands the development of virtual learning environments, an essential piece to configure the new profile required by education in Mexico and throughout the world. From a didactic perspective, the adoption of technology has become essential for the generation of knowledge and skills according to the needs of the 21st century world of work.

Today, it is not possible to understand the functioning of schools without the use and access to technology, as well as the training and training of teachers in digital tools, so the knowledge and development of skills required for the use and management of virtual environments is essential for both teachers and students.

Incorporating into teaching practice the use of electronic devices such as tablets, laptops, the use of software, as well as digital tools for virtual teaching, can make a difference in the teaching-learning processes. (Avendaño, Bohórquez y Lara, 2022).

Virtual learning environments

Virtual learning environments provide the opportunity to solve problems related to distance and access to face-to-face educational centers, as has become evident throughout the health contingency derived from the proliferation of the type 2 coronavirus that causes acute respiratory syndrome. severe (SARS-CoV-2), which forced governments and schools to migrate from the traditional face-to-face education model to virtual, online or remote models. For such models, the development of virtual learning environments is an essential bridge for the acquisition and access to knowledge (Campuzano, Rivera and Valverde, 2021).

Teaching and learning through the support of digital tools in the educational field strengthens the interactive work between teachers and students (Montealegre and Rincón, 2020). Of course, in these circumstances, access to educational technology and the Internet is an element that cannot be done without. According to Martínez, Castro, de la Fuente and Medina (2020), learning through the use of virtual environments has positioned itself as an ideal strategy in contingency situations, such as the case of the pandemic.

It is undeniable that, throughout the world, educational systems have had a great transformation to respond to the needs of students, applying strategies and didactic resources supported by technology. The challenge and at the same time the objective of the digital transformation is that the student can access a great diversity of academic content through various devices linked to information and communication technologies (ICT) (Carvajal, Ordoñez, Segura and Daza, 2022).

Virtual learning environments depend to a large extent on the organization, development and use of audiovisual resources, which allow strengthening knowledge, communication skills, improving oral expression skills, stimulating critical and reflective thinking, as well as skills cognitive, which have their origin in the development of socio-emotional skills.

Development of cognitive skills

The first theoretical sketches about cognitive skills (cognitive skills) appeared during the 50s in the Anglo-Saxon world. It is a concept that arose from the area of cognitive psychology and that referred to thought operations through which the person takes ownership of the content and the process used (Frías, Haro and Artiles, 2017).

In the 1990s, interest in the study of cognitive abilities was reactivated, but now from a different perspective. Indeed, a new theory on thinking skills (thinking skills) made its way by then. In this framework, thinking skills were seen as those that give human beings the ability to capture, process and interpret information (Frías et al., 2017).

In psychology it is considered that thinking skills need cognitive resources for the processing of mental operations. Cognitive resources do not occur spontaneously or naturally, they must be stimulated and worked through learning experiences and a training process. These skills are directly related to the thought process and form the basis of learning. More specifically, they are known as the faculties and skills that allow the transformation and discrimination of data to turn it into information (Frías et al., 2017).

Likewise, the first appearances of behavioral models were due to the demand for a system that would allow the classification of the theory and that would make it possible to measure the IQ, since until then the dimensions that were evaluated were insufficient. The models with the greatest impact were: 1) the structure of the intellect by J. P. Guilford (1967); 2) Bloom's taxonomy of educational objectives (1979); 3) Krathwohl's (2002) Revised Bloom's Taxonomy, and 4) Halpern's Taxonomy of Critical Thinking Skills (2003) (Frías *et al*., 2017).

Within cognitive abilities, comprehension is understood as a productive process that starts from data in real time and information previously stored in memory whose main objective is to arrive at an interpretation of it (Parodi, 1999, p. 20). Thus, the relationship between understanding and cognition must be given, since without cognition there is no understanding.

Cognition refers to the way the mind operates. Cognitive processes (perception, attention and memory) involve mental mechanisms that allow the capture of current data through the senses, the power to represent them in the mind and with thought to be able to relate them to information previously stored in memory, to interpret and externalize them. with an appropriate language (Fuenmayor and Villasmil, 2008).

Shaw (2014), citing Stenberg, mentions that critical thinking includes the processes, strategies, and mental representations that people use to solve problems, make decisions, and learn new concepts. Critical thinking is based on criteria of truth and is opposed to "dogmatism", which implies accepting events without questioning them. A critical thinker understands what constitutes quality reasoning and makes a serious commitment to using and conducting informed analysis (Mackay, Franco, & Villacis, 2018).

In this regard, Mcknown (1997) addressed the characteristics of critical thinking based on three principles: 1) questioning is the basis and is necessary to make deductions that come from serious evidence with a strong impact; 2) deep thought is necessary and 3) a process of concentration and orientation is necessary (Mackay et al., 2018).

Hence, critical thinking is a pillar for the identification and resolution of problems. For Perales (1993), the problem can be identified as any event that occurs unexpectedly or unexpectedly. It can generate a high level of uncertainty, in addition to a behavior with a tendency to search for a solution. Problem solving will be the term to use to refer to the process through which an uncertain situation will be analyzed and clarified and where all the cognitive knowledge and procedures on the part of the solver are put into operation. (Mackay *et al*., 2018).

Likewise, within social cognitive theory, there is self-efficacy, which is based on the individual's ability to plan and execute actions aimed at achieving established objectives and goals. Self-efficiency supposes the ability to identify the most efficient process (the use of the least resources) to achieve the objective effectively (in time and form) (Contreras et al., 2005).

The objective of this research is to identify the influence of virtual learning environments on the development of cognitive skills in men and women through a structural equation model. In this sense, derived from the literary review, as well as from the research objective, the following hypothesis is established: virtual learning environments have a positive impact on the development of cognitive abilities. To test this hypothesis, a structural equation model is used.

Materials and methods

Definition of study variables

Taking into account the previously discussed elements, it is established as an independent or exogenous variable that integrates the research model into virtual learning environments. Instead, the dependent or endogenous variable points to cognitive abilities. Therefore, it is planned to demonstrate the impact of the independent variable with respect to the dependent variable.

Exogenous or independent variable: virtual learning environments

A virtual learning environment allows students to acquire knowledge and develop learning, who has an active and responsible participation in the process, which is carried out through platforms (LMS) that allow them to acquire knowledge (Sabater, 2016).).

Virtual learning environments enable the student to learn in a self-directed way, which favors the development of skills for lifelong learning. (García, González y Muñoz, 2020).

Endogenous or dependent variable: cognitive abilities

Cognitive abilities are understood as multiple functions that our brain performs. Quantifying or evaluating them requires various tools. Here it is considered that, in tests of this type, even though they are specialized by area, the general function of the human being will always prevail, understanding that it is complex to evaluate a single function in isolation. Thus, there are global scales that weigh the cognitive state in general, commonly known as intelligence tests (Gómez, 2019).

The main tests that measure cognitive abilities are mentioned: 1) factor G test; 2) Binet-Simon test; 3) test of acquired knowledge; 4) verbal intelligence test; 5) numerical intelligence test; 6) logical intelligence test; 7) Stanford-Binet intelligence test; 8) WAIS test; 9) WISC test; 10) Raven's test; 11) Woodcock-Johnson III tests of cognitive abilities; 12) Otis-Lennon test; 13) cognitive abilities tests, and 14) Wonderlic personal test (García-Allen, 2015).

Method

The method established in this quantitative research combines the descriptive and correlational approach, since through a multivariable model the impact of independent variables is analyzed with respect to a dependent variable with the description of the sample under study. However, since virtual learning environments are a subject little studied in university students, an exploratory factor analysis (EFA) is required, following the indications of López and Gutiérrez (2019), with the aim of defining the variables observed with respect to each construct.

Subsequently, it is recommended to carry out a confirmatory factor analysis (CFA) to corroborate with greater precision, by virtue of adjustment indices, that the observed variables or items of the questionnaire are framed in the corresponding construct (Fernando et al., 2021). This lays the foundations for contrasting the empirical model proposed with the statistical one using the structural equation model (SEM) (Sujith et al., 2022). It should be noted that this methodology is very appropriate in the social sciences to explain theoretical foundations empirically when they have been little addressed.

The results of this article are based on data collected through a 13-question questionnaire designed and answered through the Google Forms platform. The aforementioned form, as can be seen in Annex I, has three sections. The first one requests descriptive data (sex, age range, educational program, stage of studies). The subsequent block of questions delves into the dimensions of cognitive skills necessary in university students (problem solving, academic progress, self-efficacy, critical thinking and comprehension). Finally, a series of questions regarding virtual learning environments (aspects such as infrastructure, resources and ICT management skills).

It is important to mention that the items of the variables that make up the research model, that is, from questions 5 to 13 (sections two and three), have a Likert-type response scale (five ranges), since it is a essential requirement to carry out structural equations. Likewise, each dimension must contain at least three questions or observable variables for the program to develop the model and its corresponding adjustment, since otherwise a structural equations methodology is not possible (Cutumisu, Adams, Glanfield, Yuen, & Lu, 2022).). The first four questions are used with the objective of describing the study sample analyzed.

Similarly, the statistical software IBM SPSS Statistics is used to carry out the AFE by reducing dimensions, where all the questions that make up the research model are rotated

to check if they are statistically grouped in their corresponding dimension, using the analysis of rotated components and the varimax method. This program is an effective tool for formulating research hypotheses and determining relationships between items as part of exploring a predictive model (Herber et al., 2020).

Another very useful statistical system, according to Sam, Brijs, Daniels, Brijs and Wets (2020), is AMOS which, as an extension of the aforementioned SPSS, helps to model structural equations that support the theory and thus complement the research objectives and monitor the behavior of the hypotheses. In this case, the maximum likelihood model is applied for a multivariate analysis with factorial regression, variance, and correlation. With this, a confirmatory research model is configured.

Population, sample and sampling methods

The sample is determined from the population universe of students of the Faculty of Accounting and Administration of the Autonomous University of Baja California (UABC). According to data provided by the academic unit, there is a total of 3,797 students distributed in common core, Computer Science, Accounting, Business Administration and International Business (UABC, 2021).

Given the characteristics of the study variables, the following equation is used, since it is a universe of less than 10,000 study subjects (Ingrith y Valeria, 2019).

$$n = \frac{N\ Z2\ p\ q}{(N - 1)\ e2 + Z2\ p\ q}$$

This is how a minimum sample of 350 elements is established, with a confidence level (Z) of 95%, a permissible margin of error (ε) of 5% and a probability of success (p) and failure (q) equal to 0.5.

Based on the previously explained, a total of 423 students were surveyed, of which 121 belonged to the common core, 108 to Accounting, 92 to Business Administration, 81 to International Business and 21 to Computer Science. That is, 193 students corresponded to the basic stage, 152 to the disciplinary stage, and 78 to the terminal stage. Of the total, 270 females were part of the sample and 153 men completed it. However, the age of 223 students ranged between 17-20 years, 146 between 21-23 years and 54 had more than 23 years of age.

The questionnaire was subjected to a reliability test using Cronbach's alpha, and satisfactory results were obtained (0.853), since it is in the desired range of 0.700-0.900, which means that the questions that make up the model are internally consistent. (Vaske,

Beaman, & Sponarski, 2017). Thus, the evaluation of the desired phenomenon is reliable, since the items on the form are statistically correlated (Table 1).

Table 1. reliability statistics

Alfa de Cronbach	Número de elementos (preguntas del cuestionario que integran el modelo)
0.853	9

Source: self made

Results

Exploratory factor analysis

First, the internal consistency of the model was evaluated with the Kaiser Meyer Olkin (KMO) index, which acquires values between 0-1 to compare the magnitudes of the coefficients in the appreciated correlation with respect to the partial correlation. Therefore, if the KMO is greater than 0.80, the intention to carry out factorial analysis is appropriate (Zacarías, 2017) In the study, an independent analysis of the research model filtered by the sex variable was carried out.

Thus, a model for women and another for men were contrasted, derived from the same database generated from the data collection instrument, all with the aim of clarifying whether there is an impact of virtual learning environments on the development of cognitive abilities, in addition to evaluating whether there is any significant difference between the students.

The model developed from the sample of women correctly fits Bartlett's sphericity test, with accepted values, since the chi-square ($\chi 2$) is 1035.675, as well as 36 degrees of freedom (DF) and a significance of o.000, which, together with a KMO of 0.882, estimates a statistically significant correlation between the items that appear in the model, as shown in Table 2. For its part, the exploratory statistical model analyzed for men provides slightly higher fit results, since the KMO in this case is 0.896, the $\chi 2$ is represented with a smaller value 765.408 and the DFs remain in the same range of 36. Similarly, the level of significance is perfect (0.000), which indicates that the proposed variables are statistically integrated under the phenomenon that raises the research hypothesis.

Table 2. KMO and Bartlett test for university students by sex

		Mujeres	Hombres
Medida Kaiser-Meyer-Olkin de adecuación de muestreo		0.882	0.896
Prueba de esfericidad de Bartlett	Aprox. ji al cuadrado	1035.675	765.408
	Gl	36	36
	Sig.	0.000	0.000

Source: self made

After passing the KMO test, the number of rotated components of the model must be extracted and determined to validate the number of constructs and their contribution to the initial model. In this sense, the total variance explained of the model by the dimensions Cognitive Skills and virtual environments of aprendizjae2 needs to be greater than or equal to 50%. This allows us to argue that the constructs that make up the model mostly explain the phenomenon in question (López and Gutiérrez, 2019).

Thus, in the case of women, a total variance of 62.068 % is appreciated, where the contribution of the Cognitive Skills construct stands out with 33.382 % of accumulated percentage (table 3). In the case of the analysis of variance by construct for men (table 3), a greater explained variance is observed, amounting to 68,413 of the total model. Likewise, the Cognitive Skills construct stands out with a 42.225% percentage contribution. Therefore, the PLE construct represents 26.188 % of the variance of the phenomenon expressed according to the sample data collected.

Table 3. Total explained variance of the model for university students by sex

Componente	Sumas de rotación de cargas al cuadrado					
	Total		% de varianza		% acumulado	
	Hombres	Mujeres	Hombres	Mujeres	Hombres	Mujeres
Habilidades Cognitivas	3.800	3.004	42.225	33.382	42.225	33.382
PLE	2.357	2.582	26.188	28.686	*68.413*	*62.068*

Source: self made

Once the analysis of variance was satisfactorily carried out in both sexes, a matrix of rotated components was established to demonstrate the contribution, in this case, of the questions in the questionnaire that as observed variables define each of the constructs that establish the research model. This is statistically explained as the correspondence of the items that make up each main component and its contribution by virtue of the covariance, which provides significant values above 0.500, although metrics of 0.300 are also accepted (Olechnowicz and Babula, 2021).

Continuing with the statistical analysis, the matrix of rotated components of the female sex is displayed, where each question integrates its corresponding construct with statistical indicators that exceed 0.565. In relation to the Cognitive Skills construct, the variance of question nine stands out, referring to the development of confidence in academic progress through remote work (0.830). Another observed variable that breaks in strongly is that of item six of the questionnaire, concerning the critical thinking provided by the distance modality (0.759). Finally, special relevance is observed in the self-efficacy construct, derived from online work in university students (0.710).

Regarding the personal learning environments construct, the importance of the role of technology in remote learning is confirmed (0.806, item 11). Likewise, item 10 highlights the need for suitable devices for virtual learning connectivity (0.798); Item 12 shows whether technological resources favor online work (0.713). Of course, this same analysis was carried out for the male segment. In this case, questions seven, eight and six stand out, which address cognitive aspects such as self-efficacy (.845), problem solving (0.829) and critical thinking (0.819). In addition to this, within the Virtual Environments construct, items 10, 11 and 13

are especially relevant, which put forward arguments related to connectivity devices (0.831), technology (0.697) and the expertise to manage ICT (0.694).

Table 4. Rotated component matrix, university students by sex

Preguntas del cuestionario (variables observadas)	Constructos (variables latentes)			
	Habilidades Cognitivas		Ambientes Virtuales de Aprendizaje	
	Mujeres	Hombres	Mujeres	Hombres
5) El trabajo en línea fortalece mi comprensión.	0.567	0.682		
6) El trabajo en línea fortalece mi pensamiento crítico.	0.759	0.819		
7) El trabajo en línea ha fomentado mi auto eficiencia.	0.710	0.845		
8) El trabajo en línea me ha ayudado a desarrollar la habilidad de resolución de problemas	0.670	0.829		
9) El trabajo en línea ha desarrollado la confianza en mi progreso académico.	0.830	0.771		
10) Cuento con un dispositivo idóneo para el aprendizaje en línea.			0.798	0.831
11) La tecnología favorece mi aprendizaje en línea.			0.806	0.697
12) Los recursos tecnológicos favorecen mi aprendizaje en línea.			0.713	0.641
13) Mis habilidades en el manejo de TIC son suficientes para el aprendizaje en línea.			0.565	0.694

Note: principal component analysis, rotation method: varimax normalization with Kaiser. The rotation has converged to six iterations.

Source: self made

Structural equations

This section of the research was carried out with the support of IBM's AMOS statistical software, which is an extension of SPSS Statistics. As described in previous sections, this program works as a stand-alone application to run a standard multivariate analysis under not only regression parameters, but also variance and correlation factors. With this, a statistical model is established that contrasts the predictive model that is proposed in a research hypothesis that provides a graphical user interface (Yang and Mohd, 2021).

However, the execution of the data with AMOS is done by applying the maximum likelihood method to illustrate the coefficients of a regression model, or to estimate the parameters of a probability distribution. This procedure can be used in a large number of situations, therefore, it is one of the most used to visualize the adjustment of the model, both saturated and independent (Chen and Yang, 2021). As a preliminary result, the fit of the model is obtained, with chi-square indicators (CMIN) and degrees of freedom (DF). Regarding the latter, if when divided, a number less than two is obtained as a result ($2 < CMIN$), this indicates a desired coefficient of correspondence of the statistical model, as commented by Rochelle et al. (2021).

Following the above, outstanding quotients are obtained here because CMIN has a value of 29.961, which, if divided by the DF, 19, results in an adjustment of 1.577, which confirms a consonance in the interaction of the research model developed to analyze the sample set of women, from the statistician's point of view. In this sense, P (significance) establishes the possibility of accepting the positive hypothesis and therefore ruling out the null hypothesis (table 5).

Table 5. Confirmatory adjustment of the model for university students by sex

Model	CMIN		DF		*P*		CMIN/DF	
	Mujeres	Hombres	Mujeres	Hombres	Mujeres	Hombres	Mujeres	Hombres
Default model	29.961	45.570	19	26	.000	.000	1.577	1.753

Source: self made

While for college men there is a desirable fit of 1.753, by virtue of a chi-square of 45.570 and 26 degrees of freedom. Likewise, a significance of 0.000 is appreciated, which means that the null hypothesis that virtual learning environments do not develop cognitive abilities is discarded for male university students. Therefore, it is glimpsed and it is affirmed that there is a significant impact of distance education in the cognitive field of such students (table 5).

Table 6 summarizes the results of special attention for a structural equations model, such as the goodness-of-fit indices of the model, for example, the comparative fit index (CFI), normed fit index (NFI) and the index of incremental adjustment (IFI).

Said indicators require taking weights above 0.900 as a manifestation of a confirmatory result, according to Rakotoasimbola and Blili (2019). However, when faced with such metrics, the squared approximation error (RMSE) should be assessed, since it establishes the anticipation adjustment with respect to the total population with optimal indicators between 0.040 and 0.080 to corroborate that the data is not biased (Liu, He, Wang and Yu, 2021).

In the case of the statistical model carried out for university women, all the normative (0.971), comparative (0.989) and incremental (0.989) adjustment indicators are almost perfect, so to rule out some type of sampling bias it is necessary to discern that the RMSEA is not greater than 0.08; but in this model it assumes an accepted parameter of 0.046, so any type of approximation error is ruled out. Therefore, the adjustment of the data is highly recommended to continue in the structural equation model.

Likewise, the model that analyzes the impact of virtual learning environments on the cognitive abilities of male university students shows adjustments supported by correlational statistics. In this sense, as can be seen in table 6 itself, NFI, IFI and CFI are values above

0.900. Likewise, RMSEA does not exceed 0.08. Thus, the model also fits correctly for the male population segment.

Table 6. Results of adjustment indices for university students by sex.

Modelo	NFI Delta1		IFI Delta2		RMSEA		CFI	
	Mujeres	Hombres	Mujeres	Hombres	Mujeres	Hombres	Mujeres	Hombres
Modelo predeterminado	0.971	0.942	0.989	0.974	0.046	0.050	0.989	0.974

Source: self made

Another important aspect is the maximum likelihood estimation of the model, which intrinsically provides the estimates for the approximate standard error (SE) criteria, the critical proportion (CR) and the standardized estimates regarding the impacting regression of each observed variable or questionnaire question, in its corresponding latent variable or construct. Starting from the relationship between the two major study variables, it can be seen that cognitive abilities (HC) are impacted by virtual learning environments (LMS) with a weighted estimate of (0.793).

Regarding cognitive abilities, what was noted in the AFE is confirmed for female university students, due to the significant contribution of question seven, referring to self-efficiency (0.774), question eight, related to problem solving (0.734) and question six, linked to critical thinking (.681), all of them analyzed within the Cognitive Skills construct. Meanwhile, for the dimension of Virtual Learning Environments, the technological component prevails: the use (0.830), the presence of technological resources (0.823) and skills in ICT management (0.706), which respectively integrate questions 11, 12 and 13 of the form (table 7).

Table 7. Results of standardized regression indices for university students by sex.

			Estimate		SE		CR		*P*
			Mujeres	Hombres	Mujeres	Hombres	Mujeres	Hombres	
HC	<---	LMS	0.793	0.775	0.131	0.219	6.848	4.731	***
P10	<---	LMS	0.583	0.476					
P11	<---	LMS	0.830	0.843	0.164	0.362	8.936	5.812	***
P12	<---	LMS	0.823	0.812	0.156	0.353	8.231	5.746	***
P13	<---	LMS	0.706	0.751	0.164	0.328	7.625	5.582	***
P5	<---	HC	0.656	0.601					
P6	<---	HC	0.681	0.783	0.126	0.215	8.871	7.550	***
P7	<---	HC	0.774	0.853	0.157	0.235	9.371	7.967	***
P8	<---	HC	0.734	0.874	0.141	0.213	9.296	8.082	***
P9	<---	HC	0.670	0.799	0.154	0.270	8.926	7.649	***

Note: maximum likelihood estimation method.

Source: self made

The model established for male college students shows similar results. As shown in Table 7, we start from a regression estimate of 0.775 of the impact of the PLE on Cognitive Abilities, only a difference of -0.02. In this sense, the contribution of questions eight (.874) and seven (.853) also stands out, to which question nine is added here, which contributes to confidence in academic progress. In relation to the questions on Virtual Learning Environments, questions 11 (0.843), 12 (0.812) and 13 (0.751) stand out, all linked to technological uses and resources, which at the same time stand out in the model of female students.

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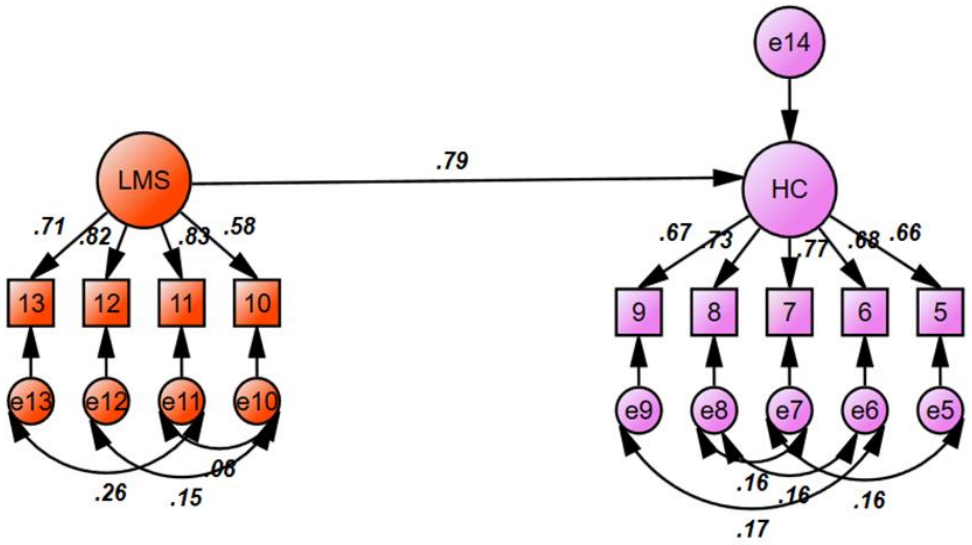
Structural analysis model for men and women

Figures 1 and 2 show, graphically, the result of the model for women and men respectively. In both cases, the independent or exogenous variable is estimated on the left and, on the right, the dependent variable that receives the impact is displayed with an arrow, which marks the level of statistical correlation. It should be clarified that the rectangles of each variable are the dimensions or items of the questionnaire that contribute to the measurement of their corresponding variable or established construct. Consequently, under the table relative to each question, circles can be seen representing error variables to assign possible measurement errors in each observable variable or item. Therefore, the difference of the regression with respect to the construct is assumed for each question of the aforementioned form.

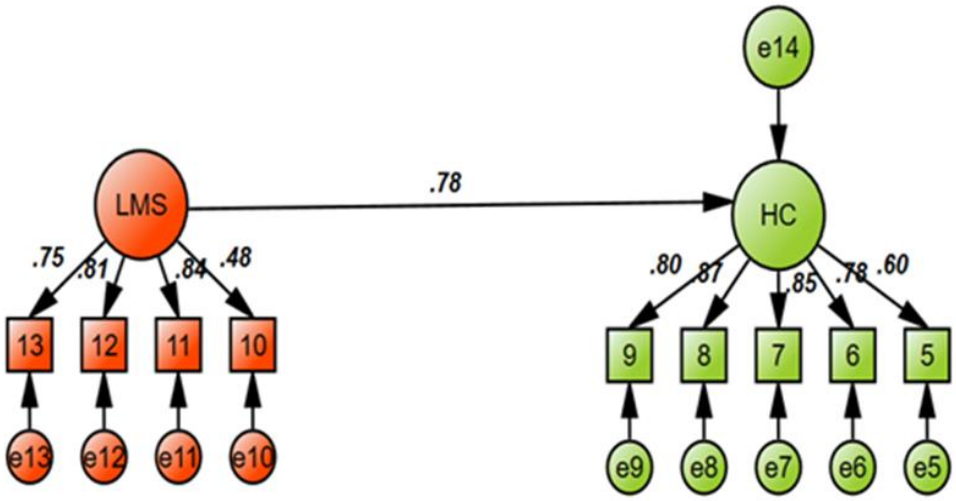
Next, it is possible to distinguish, in both cases, the positive incidence of virtual environments to generate cognitive abilities in university students with a high level of correlation. On the other hand, the difference due to sex is almost imperceptible, since the indicators for women (0.79) are very similar to those of men (0.78), so sex does not express a difference in the development of cognitive abilities. with the use of virtual learning environments.

Figure 1. Structural analysis of the model for female university students



Source: self made

Figure 2. Structural analysis of the model for male university students.



Source: self made

Discussion

Each of the objectives of this research have been verified, so the null hypothesis is rejected, since the result of the coefficient of the exogenous variables with respect to the endogenous one is greater than zero (H > 0), both for the model developed for female students and for male students. Therefore, as demonstrated by the study by Campuzano et al. (2021), Montealegre and Rincón (2020) and Martínez et al. (2020), Virtual Learning Environments have a positive impact on the development of cognitive abilities.

Thus, it is also in agreement with Mackay et al. (2018) and Contreras (2005), since the importance of cognitive skills such as self-efficiency, problem solving and critical thinking is underlined. Finally, within the Virtual Learning Environments, the technological component stands out, the presence of technological resources and the ability to use ICT. All this is demonstrated in the sample framework of students from the Faculty of Accounting and Administration of the UABC, Mexico.

However, this research identifies the influence of Virtual Learning Environments in the development of cognitive abilities from a comparative perspective between university men and women. From this perspective, a limitation is established, since there is no plausible difference between one sex with respect to the other.

Likewise, the sample of a single faculty within such an extensive and varied university environment today does not allow the results to be generalized on a larger scale. In addition to the aforementioned, the data collection instrument was applied within the

framework of the confinement situation due to the 2019 coronavirus disease (covid-19), so that currently, given the gradual and face-to-face return to activities learning conditions and perspectives of the study subjects may vary.

It is clear that in order to develop cognitive skills through Virtual Learning Environments, the use and application of technological, pedagogical and didactic resources is required, including content blogs, interactive presentations, concept maps, gamification activities and strategies, all This is mediated by the use of educational platforms, which, when developed with the aforementioned resources, allow the adoption of virtual environments, scenarios that have become essential in education in the 21st century.

For the pertinent development of virtual learning environments, there are preconditions that guarantee their effectiveness, including having the correct connectivity, as well as electronic devices for online learning, adequate knowledge of virtual platforms, as well as having specific skills. in the use and management of information and communication technologies.

Conclusions

Based on the research findings, it is stated that the statistical model of structural equations contrasts the predictive model with which the research hypothesis is proposed, and the relationship between the two major study variables is validated: it is appreciated that cognitive abilities are impacted by virtual learning environments. A good adjustment of the model is obtained, with chi-square (CMIN) and degrees of freedom (DF) indicators, and it is affirmed that there is a significant impact of distance education in the cognitive field in both men and women. The model obtained that analyzes the impact of virtual learning environments on the cognitive abilities of male and female university students also shows adjustments supported by correlational statistics.

Regarding cognitive abilities, it is confirmed for male and female university students that virtual learning environments allow the development of cognitive abilities such as self-efficiency, problem solving and critical thinking. Particularly, within the dimension of virtual environments, the technological component stands out, the presence of technological resources and the ability to use ICT.

Therefore, in both cases the positive incidence of virtual learning environments to generate cognitive skills in university students with a high level of correlation is distinguished. The development of socio-emotional skills, particularly cognitive skills, allow

people to more effectively develop self-efficacy, more accurate problem solving and critical thinking.

Future lines of research

It is recommended to investigate the guidelines and requirements to make the educational offer mediated by technology more accessible, as well as the relevance in the adoption of hybrid educational models that respond to an effective development of virtual learning environments that promote not only the acquisition and administration of knowledge, but also the development of cognitive skills, since the use of technology offers confidence in the student's academic progress.

References

Avendaño, V., Bohórquez, C. I. y Lara, P. A. (2022). Escala para medir la significación del pensamiento complejo en entornos virtuales de aprendizaje de instituciones de educación superior. *Ra Ximhai*, *18*(1), 179-192. Recuperado de https://doi.org/10.35197/rx.18.01.2022.09.va.

Bloom, B. S. (1979). *Taxonomía de los objetivos de la educación* (3.ª ed.). Alcoy, España: Marfil.

Campuzano, G., Rivera, G. y Valverde, K. (2021). Nuevos retos en México para la construcción de entornos virtuales de aprendizaje en tiempos de pandemia. *Academia y Virtualidad*, *14*(2), 75-88. Recuperado de https://doi.org/10.18359/ravi.5391.

Carvajal, N., Ordoñez, L. T., Segura, A. y Daza, J. E. (2022). Utilidad de la virtualidad en las prácticas profesionales de fisioterapia en el contexto de la pandemia COVID-19. *Retos*, *43*, 185-191.

Chen, D. and Yang, X. (2021). Maximum likelihood estimation for uncertain autoregressive model with application to carbon dioxide emissions. *Journal of Intelligent & Fuzzy Systems*, *40*(1), 1391-1399. Retrieved from https://doi.org/10.3233/JIFS-201724.

Contreras, F., Espinosa, J. C., Esguerra, G., Haikal, A., Polanía, A. y Rodríguez, A. (2005). Autoeficacia, ansiedad y rendimiento académico en adolescentes. *Diversitas*, *1*(2), 183. Recuperado de https://doi.org/10.15332/s1794-9998.2005.0002.06.

Cutumisu, M., Adams, C., Glanfield, F., Yuen, C. and Lu, C. (2022). Using Structural Equation Modeling to Examine the Relationship Between Preservice Teachers' Computational Thinking Attitudes and Skills. *IEEE Transactions on Education*,

Education, *65*(2), 177-183. Retrieved from https://doi.org/10.1109/TE.2021.3105938.

Fernando, E., Ikhsan, R. B., Surjandy, S., Condrobimo, A. R., Meyliana, M., Amalina, A. N., Nabil, M. and Melinda Syahbani, T. H. (2021). Marketing Influencer: How to Measure Purchase Intention Using Social Media - Study of Confirmatory Factor Analysis. Paper presented at the 2021 International Conference on Information Management and Technology (ICIMTech). Jakarta, September 19-20, 2021. Retrieved from https://doi.org/10.1109/ICIMTech53080.2021.9534912.

Frías, M., Haro, Y. y Artiles, I. (2017). Las habilidades cognitivas en el profesional de la Información desde la perspectiva de proyectos y asociaciones internacionales. *Investigación Bibliotecológica Archivonomía Bibliotecología e Información*, *31*(71), 201. Recuperado de https://doi.org/10.22201/iibi.0187358xp.2017.71.57816.

Fuenmayor, G. y Villasmil, Y. (2008). La percepción, la atención y la memoria como procesos cognitivos utilizados para la comprensión textual. Revista de Artes y Humanidades Unica, *9*(22), 187-202. Recuperado de https://www.redalyc.org/pdf/1701/170118859011.pdf.

García-Allen, J. (2015). Tipos de test de inteligencia. Psicología y Mente. Recuperado de https://psicologiaymente.com/inteligencia/tipos-test-de-inteligencia.

García, J. A., González, M. y Muñoz, P. C. (2020). Entornos personales de aprendizaje: un estudio comparativo entre profesores costarricenses en formación y en ejercicio. *Estudios sobre Educación*, *39*, 135-157. Recuperado de https://doi.org/10.15581/004.39.135-157.

Guilford, J. P. (1987) "Creativity Research: Past, Present and Future". En Frontiers of Creativity Research: Beyond the Basics, editado por S. G. Isaksen, 33-65.

Gómez, por R. G. (2019). Cómo medir las capacidades cognitivas. El blog de IMF. https://blogs.imf-formacion.com/blog/corporativo/neuropsicologia/como-medir-las-capacidades-cognitivas/

Halpern, D. F. (2003) Thought and Knowledge: An Introduction to Critical Thinking. New Jersey: Lawrence Erlbaum Associates

Herber, R., Kaiser, A., Grählert, X., Range, U., Raiskup, F., Pillunat, L. E. and Spörl, E. (2020). Statistical analysis of correlated measurement data in ophthalmology: Tutorial for the application of the linear mixed model in SPSS and R using corneal

biomechanical parameters. *Der Ophthalmologe, 117*(1), 27-35. Retrieved from https://doi.org/10.1007/s00347-019-0904-4.

Ingrith, Á. A. y Valeria Alejandra, R. P. (2019). *Enseñanza y aprendizaje de la estadística y la probabilidad. Propuesta de intervención para el aula*. Universidad Pedagógica Nacional.

Krathwohl, D. A. (2002). A Revision of Bloom‘s Taxonomy: An Overview. *Theory into Practice, 41*(4), 212-218.

López, M. y Gutiérrez, L. (2019). Com dur a terme i interpretar una anàlisi factorial exploratòria utilitzant SPSS. *REIRE Revista d’Innovació i Recerca en Educació, 12*(2), 1-14.

Liu, Y., He, R., Wang, S. and Yu, C. (2021). Temporal and Spectral 2D Fragmentation-Aware RMSA Algorithm for Advance Reservation Requests in EONs. *IEEE Access, 9*, 32845-32856. Retrieved from https://doi.org/10.1109/ACCESS.2021.3060375.

Martínez, M., Castro, M. A., de la Fuente, L. y Medina, D. (2020). Aprendizaje en red, una opción en tiempos de COVID-19. *Revista Cubana de Higiene y Epidemiología*, *57*, 1-14.

Mackay, R., Franco, D. E. y Villacis, P. W. (2018). El pensamiento crítico aplicado a la investigación. *Universidad y Sociedad, 10*(1), 336-342. Recuperado de http://rus.ucf.edu.cu/index.php/rus.

McKnown, K. (1997). *Fostering Critical Thinking. A Research Paper to Air Command and Staff College*. Montgomery: The Research Department Air Command and Staff College.

Montealegre, L. M. y Rincón, N. (2020). Una experiencia desde el aula universitaria en fisioterapia basada en aprendizaje colaborativo y uso de plataformas tecnológicas.. *Lúdica Pedagógica*, (32), 120-128.

Olechnowicz, A. and Babula, E. (2021). Behavioural Factors of Willingness to Save Long Term - A Factor Analysis. *Research Papers of the Wroclaw University of Economics, 65*(2), 102-113. Retrieved from https://doi.org/10.15611/pn.2021.2.07.

Perales, F. J. (1993). La resolución de problemas: una revisión estructurada. *Enseñanza de las Ciencias: Revista de Investigación y Experiencias Didácticas, 11*(2), 170-178.

Parodi, G. (1999). *Relaciones entre lectura y escritura: una perspectiva cognitiva discursiva*. Valparaíso, Chile: Ediciones Universitarias de Valparaíso.

Rakotoasimbola, E. and Blili, S. (2019). Measures of fit impacts: Application to the causal model of consumer involvement. *International Journal of Market Research*, *61*(1), 77-92. Retrieved from https://doi.org/10.1177/1470785318796950.

Rochelle, L., Campêlo, E., Pinheiro, C. A., de Carvalho, M. C., Batista, L. K. y Fernandez, R. (2021). Calidad de vida en el trabajo y salud pública: Estructura dimensional de una escala. *Enfermería Global*, *20*(2), 453-491. Recuperado de https://doi.org/10.6018/eglobal.436441.

Sam, E. F., Brijs, K., Daniels, S., Brijs, T. and Wets, G. (2020). Testing the convergent- and predictive validity of a multi-dimensional belief-based scale for attitude towards personal safety on public bus/minibus for long-distance trips in Ghana: A SEM analysis. *Transport Policy*, *85*, 67-79. Retrieved from https://doi.org/10.1016/j.tranpol.2019.11.001.

Sabater, L. (2016). Entorno personal de aprendizaje móvil (M-Ple). *3C TIC*, *5*(4), 19-37. Recuperado de https://doi.org/10.17993/3ctic.2016.54.19-37.

Shaw, R. D. (2014). How Critical Is Critical Thinking. *Music Educators Journal*, *101*(2), 66. Recuperado de http://journals.sagepub.com/doi/ abs/10.1177/0027432114544376

Sujith, A. V. L. N., Qureshi, N. I., Dornadula, V. H. R., Rath, A., Prakash, K. B. and Singh, S. K. (2022). A Comparative Analysis of Business Machine Learning in Making Effective Financial Decisions Using Structural Equation Model (SEM). *Journal of Food Quality*, 1-7. Retrieved from https://doi.org/10.1155/2022/6382839.

Sternberg, R. J. (1985). Implicit theories of intelligence, creativity, and wisdom. *Journal of Personality and Social Psychology*, *49*, 607-627.

Universidad Autónoma de Baja California [UABC]. (2021). Coordinación de Servicios Estudiantiles y Gestión Escolar de la UABC. Recuperado de https://fca.tij.uabc.mx/.

Vaske, J. J., Beaman, J. and Sponarski, C. C. (2017). Rethinking Internal Consistency in Cronbach's Alpha. *Leisure Sciences*, *39*(2), 163-173. Retrieved from https://doi.org/10.1080/01490400.2015.1127189.

Yang, L. and Mohd, R. B. (2021). Exploratory and Confirmatory Factor Analysis of PERMA for Chinese University EFL Students in Higher Education. *International Journal of Language Education*, *5*(2), 51-62.

Zacarías, J. J. (2017). Software Quality: Assessment on the Organizational, Technological and User-related Determinants in the Philippine Setting. *International Journal of*

Computing Sciences Research, *1*(2), 46-65. Retrieved from https://doi.org/10.25147/ijcsr.2017.001.1.12.

Appendant I

Table 8. Information Collection Questionnaire.

DATOS GENERALES
1) Selecciona el programa educativo al que perteneces en la actualidad
Tronco común, Informática, Contaduría, Administración de Empresas, Negocios Internacionales
2) Especifique la etapa de estudios que cursa actualmente
Básica, Disciplinaria, Terminal
3) ¿Cuál es su sexo?
Femenino, Masculino
4) Indique su rango de edad
Entre 17 y 20 años, entre 21 y 23 años, más de 23 años
HABILIDADES COGNITIVAS
5) El trabajo en línea fortalece mi comprensión.
6) El trabajo en línea fortalece mi pensamiento crítico.
7) El trabajo en línea ha fomentado mi auto eficiencia.
8) El trabajo en línea me ha ayudado a desarrollar la habilidad de resolución de problemas.
9) El trabajo en línea ha desarrollado la confianza en mi progreso académico.
ENTORNOS VIRTUALES DE APRENDIZAJE
10) Cuento con un dispositivo idóneo para el aprendizaje en línea.
11) La tecnología favorece mi aprendizaje en línea.
12) Los recursos tecnológicos favorecen mi aprendizaje en línea.
13) Mis habilidades en el manejo de Tecnologías de la Información y la Comunicación son suficientes para el aprendizaje en línea.
Nota: las opciones de respuesta para las preguntas de las variables Habilidades Cognitivas y Entornos Personales de Aprendizaje fueron: Totalmente de acuerdo, De acuerdo, Ni de acuerdo ni en desacuerdo, En desacuerdo, Totalmente en desacuerdo.

Source: self made.

Annex 1, presented in Table 8, shows the 13-question questionnaire designed and answered through the Google Forms platform, it has three sections: the first one requests descriptive data (sex, age range, educational program, stage of studies). The following block of questions delves into the dimensions of the cognitive abilities necessary in university students (problem solving, academic progress, self-efficacy, critical thinking and comprehension), finally a series of questions are presented regarding virtual learning environments (aspects such as infrastructure, resources and ICT management skills).

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