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## Presentation of the Content

In the first article we present *Alternative Analysis and Implementation of Tests to Evaluate the Efficiency of Dust Collectors in Class D (ISO-Class 8) Production Areas of Pharmaceutical Laboratories* by Peña-Montes De Oca, Adriana Isela, Arana-Ruiz, Omar and Arroyo-Aguayo, Cristina Elizabeth, with adscription at the Universidad Tecnológica de Jalisco, as the next article we present *Augmented reality in the development of engineering laboratory practices for operation and assembly processes* by Cordero-Guridi, José de Jesús, Cuautle-Gutiérrez, Luis, Uribe-Pacheco, Luis Alberto and Hernández-Mundo Kenya, with adscription at the Universidad Popular Autónoma del Estado de Puebla, as the next article we present *Systematic review of contemporary strategies in algebra teaching: Analysis of trends in the introduction of AI* by Ramírez, Moisés, González, Yesenia, Ramírez, Federico and Pedroza, Blanca, with adscription at the Instituto Tecnológico de Apizaco, as the next article we present *Anxiety, family context, and use of recreational digital media in University students during the COVID-19 contingency* by Medina-Villanueva, Samantha, Ródenas-Cuenca, Luis Tomas, Ponce-Carbajal, Nancy and Vanegas-Farfano, Minerva Thalia, with adscription at the Universidad Autónoma de Nuevo León, as the next article we present *Optimization of the vocational choice process through a digital tool* by René-Santos, Osorio, Reyna-Andrea, Rincón López and Dora-Lilia, López Angeles, with adscription at the Universidad Tecnológica de San Juan del Río, as the next article we present *Thinking about how we train those who research education and human development* by Ramos-Jaubert, Rocío Isabel, Muñoz-López, Temístocles, Espericueta-Medina, Marta Nieves and Ramírez Chávez, Jorge, with adscription at the Universidad Autónoma de Coahuila, as the next article we present *Web application for learning Mexican sign language* by Rafael-Pérez, Eva, Pérez-Sánchez, Jorge, Morales-Hernández, Maricela, and Altamirano-Cabrera, Marisol, with adscription at the Instituto Tecnológico de Oaxaca.




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## Alternative Analysis and Implementation of Tests to Evaluate the Efficiency of Dust Collectors in Class D (ISO-Class 8) Production Areas of Pharmaceutical Laboratories

### Alternativa de análisis e implementación de pruebas para evaluar la eficiencia de los colectores de polvos en áreas productivas Clase D (ISO-Class 8), de Laboratorios Farmacéuticos

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#### Abstract

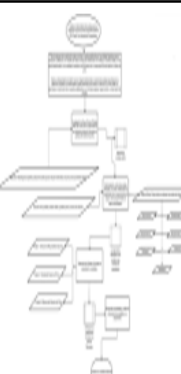

The purpose of this work is to develop and document alternative tests to evaluate dust collection efficiency in Class D production areas using flow direction and suction efficiency tests. A simple methodology was developed integrating three tests, starting with the flow direction test, followed by the suction efficiency challenge, and finally the inlet efficiency assessment test. An anemometer was used to evaluate the air extraction speed from each dust collection point, taking into account each inlet and comparing it with the equipment's technical specifications. The experimental results demonstrated that dust capture efficiency increased rapidly with the speed of the air curtain and the suction air flow rate, up to an acceptable level of 98%. Future lines of research are proposed to improve energy efficiency and/or selectivity in particle capture, considering their morphology and cohesiveness. It would also be interesting to conduct evaluations to modify the Kst (explosiveness) to mitigate risks.

#### Resumen

El propósito del presente trabajo es desarrollar y documentar las pruebas alternativas para evaluar la eficiencia de colección de polvos en áreas productivas Clase D mediante pruebas de dirección de flujo y eficacia de succión. Se desarrolló una metodología simple integrando tres pruebas, iniciando con la prueba de dirección de flujo, seguida por el reto de la eficiencia de succión, para terminar la prueba de evaluación de eficiencia de tomas colectoras, con apoyo de un anemómetro a fin de evaluar la velocidad de extracción de aire de cada uno de los puntos de colección de polvo, tomando en cuenta cada una de las tomas y contrastando con las especificaciones técnicas del equipo. Los resultados experimentales demostraron que la eficiencia de captura de polvo aumentó rápidamente con la velocidad de la cortina de aire y el caudal de aire de succión hasta un nivel aceptable del 98%. Se proponen como futuras líneas de investigación para mejorar la eficiencia energética y/o selectividad en la captura de partículas considerando su morfología y cohesividad, también sería de interés realizar evaluaciones a fin de modificar el Kst (explosividad) con la finalidad de mitigar riesgos.

Alternative Analysis and Implementation of Tests to Evaluate the Efficiency of Dust Collectors in Class D (ISO-Class 8) Production Areas of Pharmaceutical Laboratories		
Objective	Methodology	Contributions
The objective of this Project is to develop and document test to evaluate dust collection efficiency in Class D production areas by testing flow direction and suction efficiency.		

Analysis, Efficiency Evaluation, Dust Collector

Análisis e implementación de pruebas para los colectores de polvos en áreas productivas Clase D (ISO-Class 8), de Laboratorios Farmacéuticos		
Objetivo	Metodología	Contribuciones
El objetivo es desarrollar y documentar las pruebas para evaluar la eficiencia de colección de polvos en áreas productivas Clase D mediante pruebas de dirección de flujo y eficacia de succión.		

Análisis, Evaluación de eficiencia, Colector de Polvos

**Area:** Promotion of frontier research and basic science in all fields of knowledge

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## Introduction

An HVAC (heating, ventilation, and air conditioning) system. As an air conditioning system, it acts as heating in the winter and cooling in the summer. Its purpose is to provide the user with an indoor environment with comfortable temperature, relative humidity, and air purification. The components of an HVAC system incorporate heating, ventilation, and air conditioning functions. This includes filters, condenser, motor, dust collectors, filter banks, air extractors, ducts, and other electrical components.

HVAC systems can also be called air conditioning systems, as there are AC units that have a heating function. The ventilation system of these units can be natural, which is the most common, or have additional air cleaning components, such as special filters, dust evacuation, and alarm systems.

In the pharmaceutical industry, it is one of the so-called critical systems because it is vitally important to maintain the necessary parameters for the quality of medicines or medical devices. To ensure this function in the industry, the validation department is assigned the responsibility of evaluating the system, ensuring compliance with the regulatory and federal requirements indicated in the documents.

Dust collection separates dispersoids from solids in gases, which are divided into two categories: Ecological and Process.

Ecological to prevent environmental contamination, primarily in some metallurgical operations.

And Process, which is the case at hand, improves air quality in the workplace so that workers can safely perform their duties in the production of pharmaceutical products,

Installing a dust collection system improves worker safety and minimizes medical costs.

## System Design

For basic design and functionality criteria, two parameters are considered: Air velocity and Air Mass.

In dust collection, a certain capture velocity is required to direct the dirty air stream into the duct system, and a minimum conveying velocity is required to keep the product in the air stream and prevent settling. Given these two velocity requirements, the different system components can be selected for an appropriate air volume and maintain the required conveying velocity in the system.

Air mass in cubic feet of air per minute (ACFM), which considers the density of air at sea level.

Another important variable is the resistance to flow within the equipment, which is the sum of the resistance through each of the system components.

It should be noted that a dust collector using cartridge filters can separate particles up to 0.5 microns in diameter with 99.9% efficiency (by weight), while a standard HEPA filter has a particle separation efficiency of at least 99.97% (by particle count) for particles below 0.3 microns in diameter.

Collector cleaning typically involves solenoid valves and blower tubes that periodically force compressed air toward the clean side of the filters and induce rapid expansion of the filters to dislodge collected particles from the surface of the dirty side. This process is typically automated, with valves activated by a pressure sensor or a time sequencer.

The objective is to develop and document test to evaluate dust collection efficiency in Class D production areas by testing flow direction and suction efficiency.

The primary purpose of this work is to improve worker health and productivity, comply with mandatory standards, and reduce production costs.

## Theoretical framework

### *Components of a Dust Collector*

A dust collector cartridge is an important piece of equipment used to collect fine dust particles from the air. It consists of:

Filter cartridge, cartridge holder, top cover, bottom cover, O-ring o gasket, flange, bolts and nuts.

Standards related to dust collectors and cartridges include: ISO 16890:2016, which regulates the efficiency of dust collector cartridges and establishes the requirements and test methods for evaluating the performance of air filters (Funk y col., 2015). It establishes four particle filtration efficiency classes based on particle size in microns: PM1, PM2.5, PM10, and ePM1.

Filtration efficiency is determined by measuring the number and size of particles passing through the filter under specific test conditions. To better characterize the particles; in addition to the influence of their shape and size, other parameters such as sphericity and flow void fraction must be examined (Reina and col., 2000). Fluidization velocities are the key parameter for optimal transport (Reina and col., 2000; Xu and Zhu, 2006; Xu and Zhu, 2008; Gomes and Mesquita, 2014).

Thus, the main parameters driving dust collection systems are multiphase flow velocities and pressure differentials (Reina and col., 2000; Xu and Zhu, 2008; Wang y col., 2006; Huang y col., 2018), which are velocity-dependent.

## Methodology

The type of non-experimental technological research (Cegarra-Sánchez, 2004) which seeks to evaluate dust collection to improve the environment in Class D productive areas.

### Box 1



**Figure 1**

Dust Collector Donaldson

There test were included, beginning with the flow direction test, followed by the suction efficiency test, and finally the intake efficiency test, supported by an anemometer to evaluate the air extraction speed from each of the dust collection points, taking into account each intake and comparing it with the equipment's technical specifications (Miranda-Estrada, 2013).

### *Dust suction check*

An area with volatile (dense) dust was simulated. Test the dust collection inlet to ensure it meets the capacity to absorb the defined amount of surrounding dust in the defined area and the areas that constitute the equipment itself. Record the data obtained.

### *Airflow Profile Verification*

A gas mist (water-based, safe for health) was generated at a distance of 10 to 20 cm from the periphery of the dust collector inlet. Once the flow profile is visible, verify that it meets the acceptance criteria. Upon completion, photograph the resulting profile and record the data.

### *Dust Collection Intake Efficiency Check*

The anemometer cup was placed 5 to 10 cm away from the dust collector inlet, previously configured from the corresponding surface size and velocity readings were taken.

Once the measurements were completed, the results were totaled and compared with the acceptance criteria. Finally, the data obtained were recorded.

For the purposes of this work, a 99.97 micron efficiency cartridge was used, providing the required amount of dust retention extracted from the production areas involved, ensuring compliance with the air extracted to the outside.



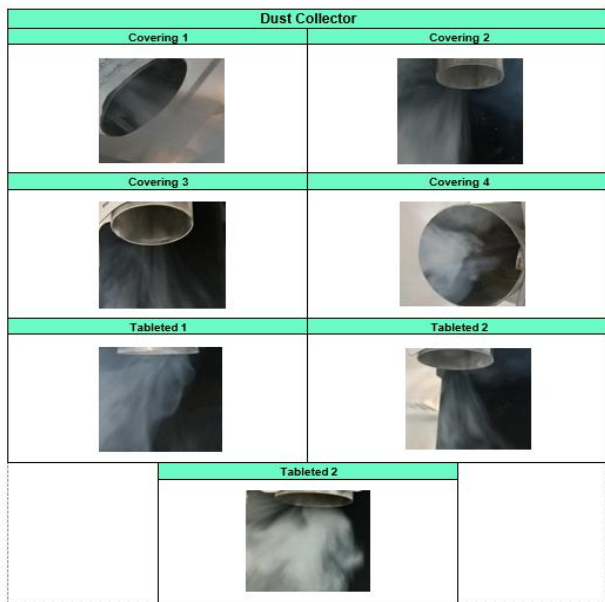
**Box 5**



**Figure 5**  
Smoke Test

The collection inlets of coatings 1 to 4 and tableting machines 1 to 3 meet acceptance criteria; the suction of volatile particulate matter, caused during the working period, on the periphery of the dust collection inlet, presented a direct suction flow to the medium-density dust. An effective response is observed in terms of compliance with the implementation requirements, thus meeting the requirements specified by the equipment supplier.

**Box 6**



**Figure 5**  
Airflow Profile Verification

The collection inlets for coatings 1 to 4 and Tableting Machines 1 to 3 meet the acceptance criteria, the suction direction shows no flow variation or intermittent operation, which allowed the gas mist to be sucked in without expulsion.

The experimental results for the smoke curtain efficiency test showed that smoke capture efficiency increased rapidly with the speed of the air curtain and the suction air flow rate, resulting in an efficiency of 100%.

**Box 7**

Dust Collector		
Covering 1	Covering 2	
257,97 CFM Liters Per Minute EQUIP. NUMBER	254,75 CFM Liters Per Minute EQUIP. NUMBER	
Covering 3	Covering 4	
266,67 CFM Liters Per Minute EQUIP. NUMBER	260,86 CFM Liters Per Minute EQUIP. NUMBER	
Tableted 1	Tableted 2	
257,06 CFM Liters Per Minute EQUIP. NUMBER	254,75 CFM Liters Per Minute EQUIP. NUMBER	
<th>Tableted 2</th>		Tableted 2
250,19 CFM Liters Per Minute EQUIP. NUMBER		

**Figure 7**  
Dust Collection Intake Efficiency Check

**Box 8**

**Table 1**  
Interpretation of Efficiency Results

Collector intake	Acceptance Criterion	Result			Complies Yes/ No
		Reading	CFM		
Covering 1	2,000 CFM / 3,390 m <sup>3</sup> /h A 1600 CFM / 27184 m <sup>3</sup> /h	257.67	CFM	Total: 1802.25 CFM	Yes
Covering 2		254.75	CFM		Yes
Covering 3		266.67	CFM		Yes
Covering 4		260.86	CFM		Yes
Tableted 1		257.06	CFM		Yes
Tableted 2		254.75	CFM		Yes
Tableted 3		250.19	CFM		Yes

## Conclusions

The dust collector is adequate for the conditions and standards within the required cubic meter capacity, as shown by the simulation results.

By reducing the amount of dust and pollutants in the environment, a healthy and safe working environment was created for employees.

Machinery maintenance cost were reduced, productivity improved by 7%, and the risk of accidents due to this cause was reduced.

Future lines of research are proposed to improve energy efficiency and/or selectivity in particle capture, considering their morphology and cohesiveness. It would also be interesting to conduct evaluations to modify the Kst (explosiveness) to mitigate risks, so as well, it is recommended too, test laser diffraction. It should be noted that this study is not without limitations derived from the selection of analyses, therefore, it should be treated with caution.

## Conflict of interest

The authors declare no interest conflict. They have no known competing financial interests or personal relationships that could have appeared to influence the article reported in this article.

## Author contribution

*Peña-Montes De Oca, Adriana Isela:* Contributed to the management of economic resources for carrying out research and publication, as well as such translation into English in the presentation of the article, academic coordination with students, data analysis and review of the article.

*Arana-Ruiz Omar:* Contributed to the project idea, research method and, data analysis and review of the article.

*Arroyo-Aguayo Cristina Elizabeth:* Contributed to research method and data analysis and review of the article.

## Availability of data and materials

The authors may make unshared data used to generate the results reported in the article available to interested parties upon request.

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## Augmented reality in the development of engineering laboratory practices for operation and assembly processes



### Realidad aumentada en el desarrollo de prácticas de laboratorio de ingeniería para procesos de operación y ensamble

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#### Abstract

The application of a digital augmented reality model for the development of time and motion study laboratory practices is presented. Based on an existing block-based practice model, computational models were generated for the study of an augmented reality model. These models replace the typical two-dimensional model of images and information with a three-dimensional application that allows a better understanding of the movements for assembling the practice in its different stages, in addition to facilitating the understanding of the task to be performed. Based on the developed model, a survey was conducted among the participants to assess different properties of the augmented reality model, resulting in an adequate score for the evaluation of the model and the understanding of the tasks to be performed in the practice, although with some points of improvement in matters of technological adaptability.

#### Resumen

Se presenta la aplicación de un modelo digital de realidad aumentada para el desarrollo de prácticas de laboratorio de estudio de tiempos y movimientos. A partir de un modelo de prácticas existente basado en bloques armables, se generaron modelos computacionales para el estudio de un modelo de realidad aumentada, que sustituye el modelo típico de imágenes e información bidimensional, por una aplicación tridimensional que permita una mejor comprensión de los movimientos para el armado de la práctica en sus diferentes etapas, además de facilitar la comprensión de la tarea a realizar. A partir del modelo desarrollado, se realizó una encuesta a los participantes para valorizar diferentes propiedades del modelo de realidad aumentada, resultando en una puntuación adecuada para la valorización del modelo y la comprensión de las tareas a realizar en la práctica, aunque con algunos puntos de mejora en cuestiones de adaptabilidad tecnológica.

Augmented reality in the development of engineering laboratory practices for operation and assembly processes		
Objective	Methodology	Contribution
 Development of an augmented reality model for conducting time and motion laboratory practices	 Development model with digital modeling, object programming in augmented reality and validation in laboratory practice	 Digital model based on augmented reality and its comparison with conventional strategies for timing and motion of assembly operations

Realidad aumentada en el desarrollo de prácticas de laboratorio de ingeniería para procesos de operación y ensamble		
Objetivos	Metodología	Contribución
 Desarrollo de modelo de realidad aumentada para la realización de prácticas de laboratorio de tiempos y movimientos	 Modelo de desarrollo con modelación digital, programación de objetos en realidad aumentada y validación en práctica de laboratorio	 Modelo digital basado en realidad aumentada y su comparación con estrategias convencionales de tiempos y movimientos de operaciones de ensamble

Industrial Engineering, augmented reality, practical work, laboratory

Ingeniería Industrial, realidad aumentada, practicas, laboratorio

**Area:** Development of cutting-edge strategic technologies and open innovation for social transformation

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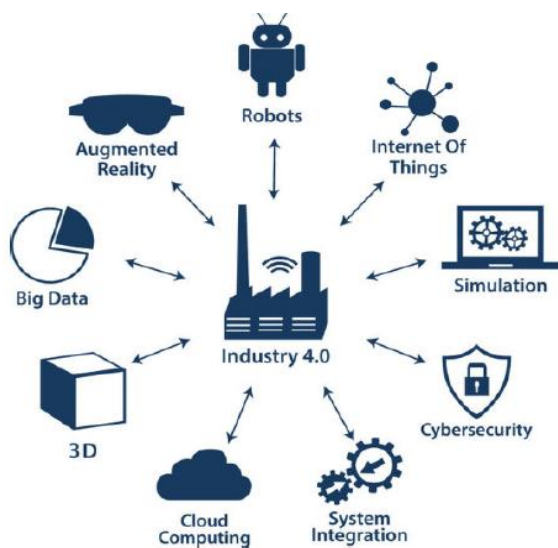
Peer review under the responsibility of the Scientific Committee MARVID<sup>®</sup>. in the contribution to the scientific, technological and innovation Peer Review Process through the training of Human Resources for continuity in the Critical Analysis of International Research.



## Introduction

Currently, the digitalization of industrial processes has emerged within technological developments. Industry 4.0, a term related to the use of various intelligent digital technologies in manufacturing processes for the creation of smart factories and production optimization. Its main technological components can be seen in Figure 1.

### Box 1



**Figure 1**

A technological environment used by Industry 4.0

Source: [1]

One of the elements belonging to Industry 4.0 is Augmented Reality (AR). This technology allows the user to perceive the real world around them through virtual elements that are superimposed through various technological devices such as smartphones, tablets or virtual reality devices (Cuautle & Cordero, 2019). This technology, which was developed prior to its incorporation into Industry 4.0 solutions, incorporated within its advances in the industry, the handling and manipulation of virtual models within the real environment. The creation of 3D environments is not new, but developers have traditionally had to use 2D interfaces to build 3D experiences. Using AR, the full 3D space is used, which is unprecedented, and defines many of the imminent changes in Human-Computer Interaction (HCI) (Papakostas et al., 2021).

There are two types of processes where the industry has applied AR: industrial processes and learning processes. Both processes have as a fundamental element, integrating digitalization into company settings in all areas, from production to human resources [4].

Regarding learning, work is being done on the training and education of industrial operations that are currently carried out using various traditional methods, where training areas deal with various problems to recreate scenarios that provide adequate training for workers. Learning protocols can be both expensive and slow. In this way, any advance in technology or methodology that could reduce the cost will be of great relevance to many people, organizations, and industries (Kaplan et al., 2020).

In terms of leveraging both human and technological resources, AR represents a fundamental tool for training and education processes for the industry in general. These augmented reality features provide a highly immersive and interactive virtual experience for users, allowing them to observe, interact, and create a digitally enhanced reality individually or collectively. In recent years, rapid technological advancements in smartphones and wearable devices have made AR technology more accessible and affordable, and therefore have ignited people's enthusiasm for its use in an educational context (Han et al., 2022). The portability of hardware and the increasingly accessible software for AR applications in training processes have led to a growing interest in this application.

In this sense, the transition from engineering education courses requires careful design and the combination of traditional manufacturing techniques with the technologies introduced by Industry 4.0, giving way to Engineering 4.0, which leverages advanced visualization technologies such as AR to facilitate the teaching process, and on the other hand, methods and workshops that familiarize future engineers with these technologies. Therefore, it is necessary to define laboratory activities with the technologies described, as well as collaborative work strategies for the development of activities in engineering projects (Caballero-Morales et al., 2020).

Similarly, the need for training and development, under human resources standards, includes providing tools such as AR to improve employee performance. AR can reduce training time for new employees and reduce their skill requirements by significantly reducing the impact of previous experiences on the learning process.

Three important characteristics of vocational training can be mentioned: first, its educational purpose, which focuses on employee development (e.g., skill acquisition and knowledge growth) rather than performance improvement. Second, the target learners are employees and professional staff rather than degree-seeking students. Third, it is specific to work activities and highly contextual, and therefore often occurs in the workplace rather than in traditional classroom settings (Han et al., 2022). In the educational context, many AR applications for learning have been created in a wide variety of domains and for all educational levels, from early childhood to higher education (Acosta et al., 2019). Training simulators are based on the use of a specific training task. Their essence is that, in a short period of time, using different methods of working with material, students can be quickly taught to remember it (Kompaniets et al., 2019). Work process education in industry, under the academic aspect, involves preparing learners to develop strategies that they can implement when entering the industry. AR applications can contribute to creating AR learning experiences that effectively support student motivation (Acosta et al., 2019). AR tools in this regard serve to implement new strategies and methods in student knowledge, which can be put into practice in industrial processes.

### Project Approach

As part of the industrial engineering curriculum, there is a methods and ergonomics laboratory, where activities related to industrial ergonomics, work measurement, and primarily time and motion study are developed. An image of this laboratory can be seen in Figure 2.

#### Box 2



**Figure 2**

UPAEP Methods and Ergonomics Laboratory

Source: Prepared by the authors

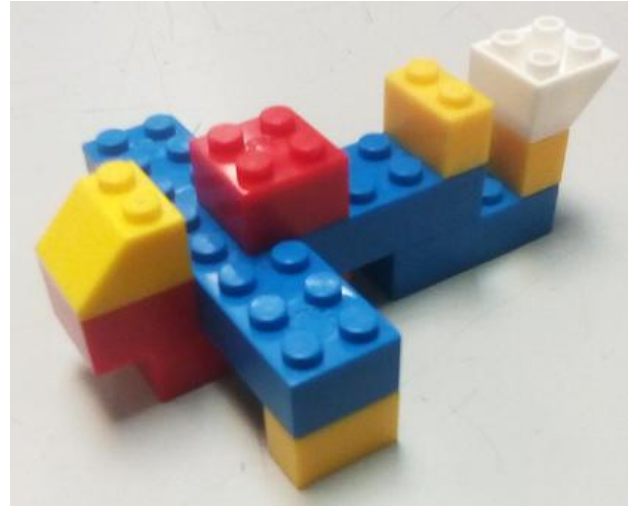
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Of all the practices, there is one practice related to the study of times and movements, specifically of products that can be assembled using Lego pieces in a total of 7 different stations, as shown in Figure 3.

#### Box 3



**Figure 3**

Product assembly in the Methods laboratory

Source: Prepared by the authors

The assembly process of the base piece of the practice depends on the adjustment of the assembly operations at the stations, but mainly on the visual and spatial understanding of the same, as seen in Figure 4.

#### Box 2



**Figure 4**

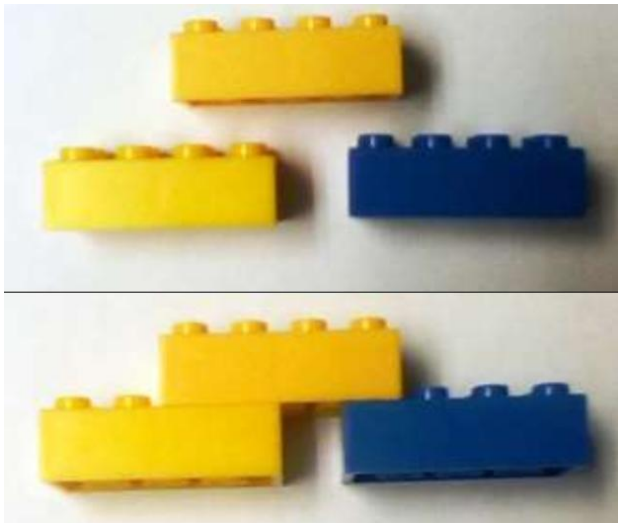
Assembly process at UPAEP workstations

Source: Own Elaboration

Cordero-Guridi, José de Jesús, Cuatle-Gutiérrez, Luis, Uribe-Pacheco, Luis Alberto and Hernández-Mundo Kenya. [2025]. Augmented reality in the development of engineering laboratory practices for operation and assembly processes. 9[21]1-9: e2921109  
<https://doi.org/10.35429/JTE.2024.9.21.2.1.9>

The assembly process requires work instructions, which are typically generated graphically for students. Information of this kind is available at each station so students can analyze and execute the assembly instructions. An example of this graphic is shown in Figure 5.

### Box 5



**Figure 5**

Current work instructions for the UPAEP methods laboratory

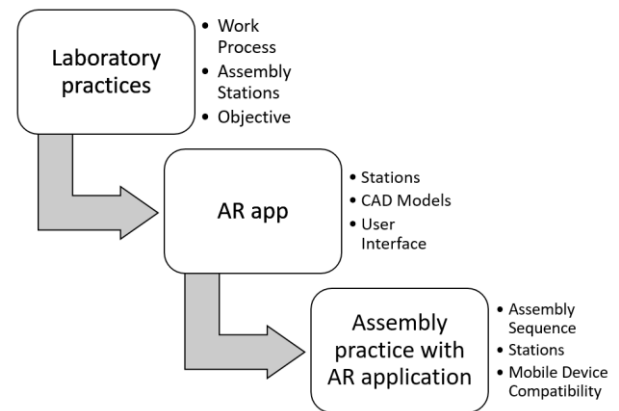
*Source: Prepared by the authors*

Due to graphic and two-dimensional limitations, the creation of a corresponding augmented reality application was proposed, seeking to improve students' timing, movements, and understanding of these practices.

### Planning

The app implementation took into account laboratory regulations and the capabilities of augmented reality applications. Considering the different workstations, CAD models were created for each. With this in mind, kinematic actions were developed using augmented reality tools to describe the assembly operation, along with an interface to identify the respective assembly station. This process is described in Figure 6.

### Box 6



**Figure 6**

AR Application Development Methodology for Assembly Sequencing

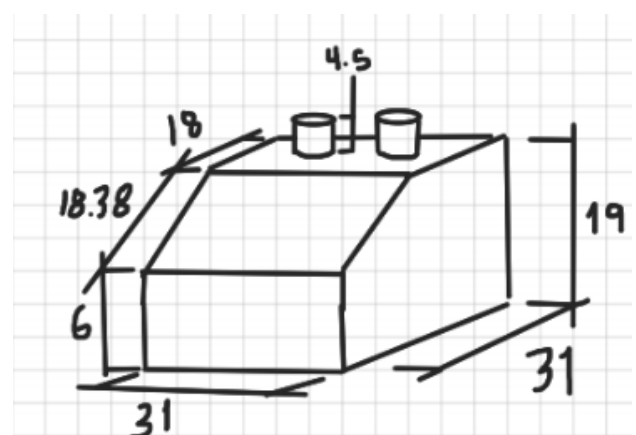
*Source: Prepared by the authors*

This process includes pre-test feedback from groups of students during lab sessions regarding the technical information and the application's interface. Among the resources used, Unity was used for the AR application. Additionally, the Vuforia augmented reality software development kit was used, as well as SolidWorks CAD drawing software.

### Approach to the augmented reality model

To develop the application, the components required to assemble the product from the methods laboratory practices were initially defined. To do this, the overall dimensions of various blocks were determined. This procedure shows the development of one of the components for assembly at station 30, as shown in Figure 7.

### Box 7



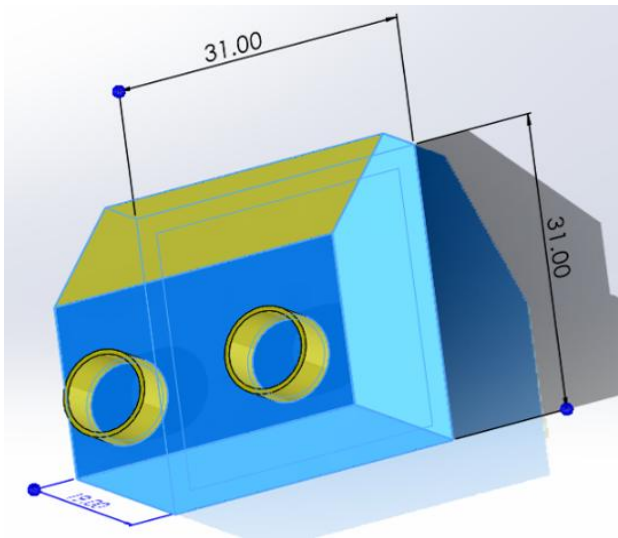
**Figure 7**

Description of blocks for 3D CAD modeling

*Source: Prepared by the authors*

Once the information was completed, different blocks were modeled in 3D CAD software, with the specifications for the blocks to be used in the actual assembly process. This is shown in Figure 8.

### Box 8



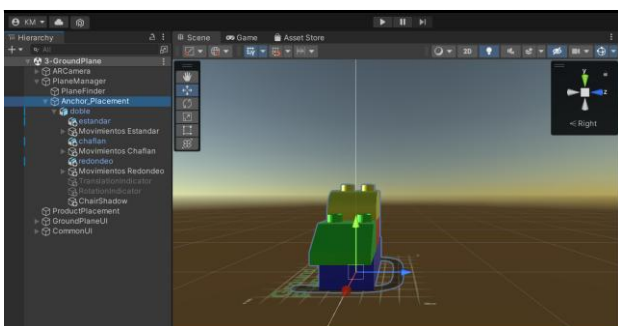
**Figure 8**

Modeling of components in station assembly

*Source: Own Elaboration*

Once the assembly models were obtained, the AR content was prepared for import into Unity. To do this, the project was imported into Unity's online resources, using Vuforia Core Samples and Vuforia Engine. A new project was created in Unity with version 2021.3.4. Once this was done, some excess files were deleted from the scenario, and the first part of the model was chosen (this part will be the base of the simulation and will be immobile in the assembly procedure shown), and the remaining parts required for the model were defined (these will be mobile in the procedure). This is shown in Figure 9.

### Box 9



**Figure 9**

Definition of fixed and moving components in assembly simulation

*Source: Prepared by the authors*

Additionally, the movement script programming was prepared, this script is shown in figure 10.

### Box 10

```

1  using System.Collections;
2  using System.Collections.Generic;
3  using UnityEngine;
4  public class Chaffan : MonoBehaviour
5  {
6
7      [SerializeField]
8      private MovimientosChaffan _waypointPath;
9      [SerializeField]
10     private float _speed;
11     private int _targetWaypointIndex;
12     private Transform _previousWaypoint;
13     private Transform _targetWaypoint;
14     private float _timeToWaypoint;
15     private float _elapsedTime;
16
17     void Start()
18     {
19         TargetNextWaypoint();
20     }
21     void Update()
22     {
23         float elapsedPercentage = 0.0f;
24         _elapsedTime += Time.deltaTime;
25         elapsedPercentage = _elapsedTime / _timeToWaypoint;
26         elapsedPercentage = Mathf.SmoothStep(0, 1, elapsedPercentage);
27         transform.position = Vector3.Lerp(_previousWaypoint.position, _targetWaypoint.position, elapsedPercentage);
28         if (elapsedPercentage >= 1)
29         {
30             TargetNextWaypoint();
31         }
32     }
33     private void TargetNextWaypoint()
34     {
35         _previousWaypoint = _waypointPath.GetWaypoint(_targetWaypointIndex);
36         _targetWaypointIndex = _waypointPath.GetNextWaypointIndex(_targetWaypointIndex);
37         _targetWaypoint = _waypointPath.GetWaypoint(_targetWaypointIndex);
38         _elapsedTime = 0;
39         float distanceToWaypoint = Vector3.Distance(_previousWaypoint.position, _targetWaypoint.position);
40         _timeToWaypoint = distanceToWaypoint / _speed;
41     }
42 }

```

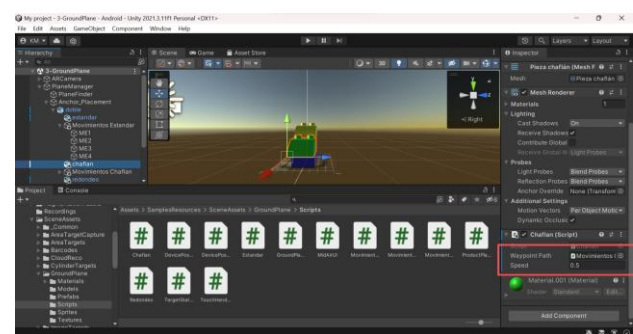
**Figure 10**

Programming movements in the assembly parts

*Source: Prepared by the authors*

Next, for each part, a script was assigned with its respective movements in the “Waypoint Path” box, while in speed, give a speed of 0.5 (this can be modified to improve the user experience), as shown in figure 11

### Box 11

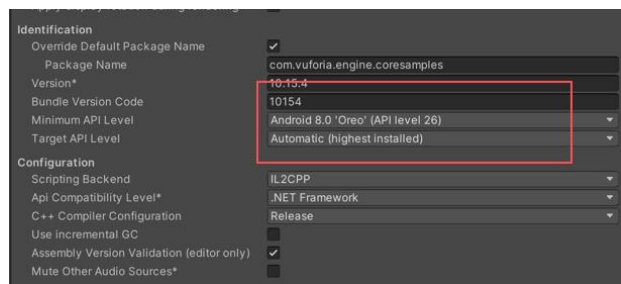


**Figure**

Assignment of movement programming to parts

*Source: Own elaboration*

With this, the station is programmed with the movements required for the parts in the assembly. The final step is to create the application or build it so it can be installed on a mobile device. The overall process consists of the "Build Settings" section, where some operating variables must be assigned for the mobile device. This is shown in Figure 12.

**Box 13****Figure 12**

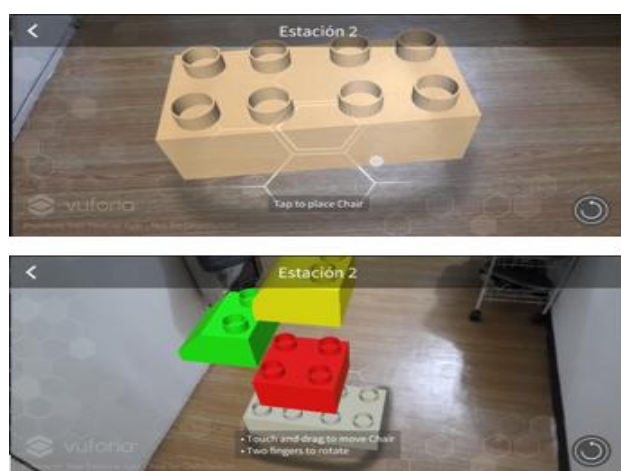
AR app build for Android device installation

*Source: Own Elaboration*

Finally, the options are accepted and the respective APK file is generated for installation on the mobile device.

**Application of the augmented reality model**

The result of the previous programming is an application that graphically and animatedly displays the assembly process, positioning the parts for the product described above. When the application is opened, the user must automatically point to a flat object that represents the ground in the user's environment using the phone's camera. Once found, it will display the base piece at ground level. As soon as the user clicks on the area where the model is to be "placed," it will begin the previously programmed sequence of movements. At all times, the application allows the model to be moved through the detected environment, as well as rotated for a better appreciation of the movements to be performed. Figure 13 shows an example of this positioning and activation of the application function.

**Box 13****Figure 13**

Movement and rotation operation of station 30 of the AR assembly application

*Source: Prepared by the authors*

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This positioning, movement, and rotation of the assembly model, along with the animation of the product's work order, are intended to provide the student in charge of assembly at that station with the maximum understanding necessary to perform their task. It is important to mention that the application developed at this time is not intended to measure the time taken to complete the activity, but rather to serve as a tool to improve understanding of the proposed assembly process.

After developing the application, it was decided to conduct laboratory tests with a predetermined number of students involved in the laboratory activities. These students were enrolled in the Automotive, Industrial, Aerospace, Mechatronics, and Bionics Engineering programs, ranging in age from 18 to 24. The test consisted of the students viewing the application and its instructions for approximately 5 minutes, and then asking them to complete the visualized assembly. Some images from the test are shown in Figure 14.

**Box 14****Figure 14**

Assembly test using an augmented reality application

*Source: Prepared by the authors*

Once they finished the assembly, they were asked to fill out a questionnaire with various questions which are shown in Table 1.

**Box 15**

	Question
1	Using the AR device was simple and the lab space was adequate for its practice.
2	The CAD/AR model used allows for proper immersion in an assembly process of the proposed model.
3	The environment used (colors, images, interface) was adequate to represent the model intended to be assembled.
4	The movements shown for the model were adequate and the trajectories generated a sense of security when assembling the physical model.
5	The speed used in the AR model was adequate to understand the assembly process.
6	The observation duration of the AR model was adequate to understand the assembly process.
7	The augmented reality experience was adequate to understand the physical assembly process.
8	The experience was pleasant from the point of view of physical integrity (eyes, touch, etc.)

**Table 1**

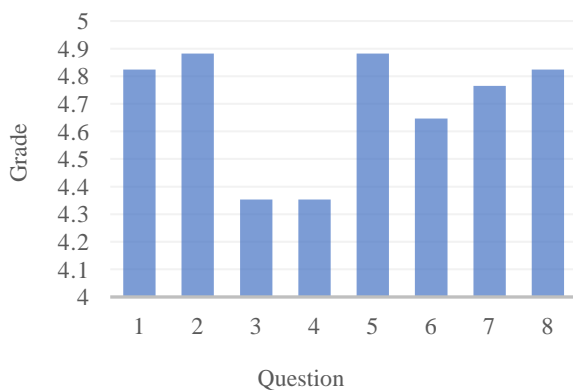
Augmented Reality Application Evaluation Questionnaire for the Assembly Process

Source: Prepared by the authors

The questionnaire was graded on a 5-point Likert scale, with the highest possible score being desirable. The questions took into account aspects of the application's quality regarding clarity and ease of use, but also aspects of the students' experience in using it to deepen their understanding of the intended assembly exercise.

**Results**

Based on the above, surveys were obtained from 17 students of the profile described above, who in their opinions reported the results shown in graph 1.

**Box 16****Graph 1**

Participant evaluations of the augmented reality application experience for laboratory practice

Source: Prepared by the authors

It was observed that the students understood the augmented reality application adequately, and its essential functioning was adequate, achieving optimal results. Furthermore, the augmented reality experience and its relationship to the physical assembly activity were adequate, with visible areas for improvement. Finally, the environmental aspects used in the application design and the movements shown in the application need to be improved for users.

**Conclusions**

The presented work describes the approach and development of an augmented reality tool for training and/or instruction in assembly tasks at the UPAEP Methods and Ergonomics Laboratory. As part of the laboratory practices taught in the laboratory, students are taught the analysis of various factors involved in a product assembly process, with the goal of being able to implement these studies in their future professional careers.

The practices described in the document relate to various workstations, which are currently described through printed images, where students must assimilate the order from sheets of paper at each of the workstations. Through discussions with the laboratory and practical instructor, an augmented reality process was conceived for these stations, based on 3D modeling and subsequent programming in Unity. This enabled the development of augmented reality workstations that allow for assembly manipulation, providing a better understanding of the assembly task for the students involved on these practices. In this way, the shipyard workshop is replicated, in which operators shared a similar experience, viewing each virtual object positioned in the same physical location and state (Vidal-Balea et al., 2020).

Additionally, a test of the tool's functionality and application was conducted with students associated with the laboratory, yielding interesting results for the correction and development of a second version of the application. These initial results provide satisfactory data on the application's use, the user's understanding of the work process, and its relationship to proper assembly. However, further work is needed on a comprehensive evaluation of the students' empirical process.

The results of this type of training and coaching tools, mean for students not only the learning of technological applications of Industry 4.0 and Engineering 4.0, but also the implementation in the work process in future professional practices and tasks. Similar to our work, different types of AR applications for work instructions were compared, and subsequently an application for a specific assembly was developed, where it is concluded through the types of visualizations of the components to be assembled, that applications with greater graphic manipulation and animations allow a better understanding of the process to be executed (Jasche et al., 2021).

A future work objective is based on the improvement of the instruments for the evaluation of the application with respect to its usability with users, where the comparative evaluation of the traditional methodology existing in assembly practices and the application of augmented reality is an important point to address.

### Conflict of interest

The authors declare no conflicts of interest. They have no known competing financial interests or personal relationships that could have influenced the work reported in this article.

### Authors' contribution

The contribution of each researcher to each of the points developed in this research was defined based on:

*Cordero-Guridi, José de Jesús:* Contributed to the development of the conceptual and programming proposal for the augmented reality experience and to its validation before its application in classroom practices, as well as to the administration of the test with the selected groups.

*Cuautle-Gutiérrez, Luis:* Contributed to the review of the state of the art and the rationale for augmented reality practices for practical work in industrial engineering areas, as well as the review of the information obtained from the tests.

*Uribe-Pacheco, Luis Alberto:* Contributed to the planning of the industrial engineering groups and to the design of the environment and the selected practices for the application of the augmented reality model.

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*Hernández-Mundo Kenya:* Developed the CAD models and the augmented reality experience, as well as the testing with the selected groups.

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### Abbreviations

AR – Augmented Reality

CAD - Computer-Aided Design

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## Systematic review of contemporary strategies in algebra teaching: Analysis of trends in the introduction of AI

### Revisión sistemática de estrategias contemporáneas en la enseñanza del álgebra: Análisis de tendencias en la incursión de la IA

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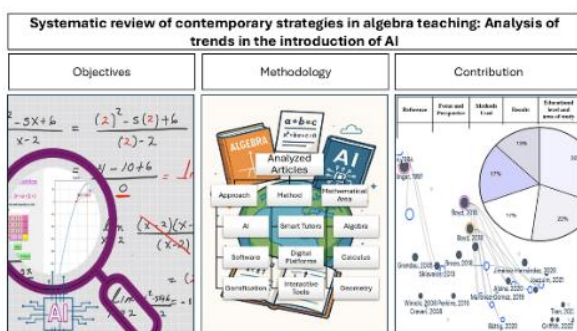


#### Abstract

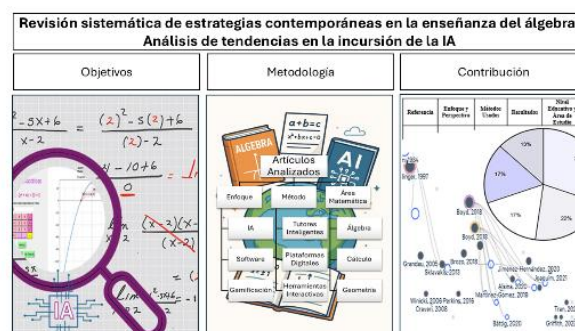
The research explores three interconnections in algebra teaching. First, an analysis of Learning Styles is presented. The relationship between these studies emphasizes the need to adapt algebra teaching to create effective learning environments. Second, studies on Innovative Educational Methods are analyzed. The exploration focuses on the integration of technologies as key facilitators, establishing a connection between reflective and collaborative pedagogical approaches. Finally, Artificial Intelligence in Education is explored. The studies characterize AI as a means for personalizing and adapting learning. In conclusion, this paper presents a projective view of the identification of individual differences in learning, the development of methodologies to address them, and AI as a force for integration.

#### Resumen

La investigación explora tres interconexiones en la enseñanza del álgebra. Primero, un análisis acerca de los Estilos de Aprendizaje, la relación entre estas investigaciones enfatiza la necesidad de adaptar la enseñanza del álgebra para crear entornos de aprendizaje efectivos. En segundo lugar, se analizan estudios sobre Métodos Educativos Innovadores, la exploración se enfoca en la integración de tecnologías como facilitadores clave estableciendo una conexión entre los enfoques pedagógicos reflexivos y colaborativos. Finalmente, se explora la Inteligencia Artificial en la Educación, los estudios caracterizan a la IA como un medio para la personalización y adaptación del aprendizaje. En conclusión, es una visión proyectiva de la identificación de diferencias individuales en el aprendizaje, el desarrollo de metodologías para abordarlas y la IA como fuerza de integración.



Teaching Algebra, Innovative Teaching Methods, Artificial Intelligence in Education



Enseñanza del Álgebra, Métodos de Enseñanza Innovadores, Inteligencia Artificial en Educación

**Area:** Promotion of frontier research and basic science in all fields of knowledge

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## Introduction

The teaching of mathematics, and algebra in particular, at the university level is often influenced by a stereotypical approach that follows the traditional "blackboard-notebook-test" model. This conventional method seeks infallible results but ignores a variety of teaching strategies that are essential for fostering effective learning. In recent years, numerous researchers have explored various adaptations and adjustments that can optimize the teaching and learning of algebraic language. This research analyzes the theoretical positions surrounding this language, including the creation of specific educational environments for algebra instruction and the design of educational strategies that provide multiple opportunities to enrich pedagogical practices.

The current context of algebra instruction presents significant challenges while simultaneously encouraging students to explore creative problem-solving approaches and develop robust arguments to support their conclusions. Furthermore, additional factors directly impact the creation of environments conducive to a proper understanding of algebraic language.

These include teacher absenteeism, classes focused primarily on abstract theoretical readings, a lack of clear objectives, the absence of effective teaching methods, and inefficient management of teaching resources, among other limiting factors. This research explores theoretical perspectives on the problems that tend to generate academic underachievement and school dropout; inferences about students unable to adopt proactive approaches under these circumstances; and how they face significant difficulties in absorbing educational content and constructing their own knowledge.

Consequently, many of the cited studies are dedicated to addressing these challenges from different perspectives. The field of education has seen significant progress in recent decades, specifically in the academic sphere related to university-level algebra instruction. In particular, there has been advancement in the integration of innovative technologies with effective pedagogies explicitly designed to improve educational processes related to this specific topic.

The research also explores the increasing incorporation of existing educational technologies in the classroom, as well as innovative methodologies applied to mathematics education, which is currently a central focus of significant research interest. The following section presents an analysis of the current state of affairs, considering all the elements involved. The first section examines theoretical perspectives on studies related to learning and teaching styles in algebra. The second section analyzes studies related to innovative educational methods, and the third section concludes the theoretical analysis with studies related to artificial intelligence in education.

## 1. Studies related to Learning and Teaching Styles in algebra

Learning styles are a recurring theme in educational literature. [Reyes Meza et al. \(2021\)](#) explored the relationship between learning styles and mathematical performance over time and concluded that the reflective style is dominant among students. This learning style is most strongly correlated with success in mathematics learning (object-oriented learning style [OOS]); therefore, educational models should be modified according to dominant learning styles to improve academic performance. [Reyes Meza et al. \(2021\)](#).

[Coll, Craveri, and Anido \(2008\)](#) analyzed the correlation between learning styles and performance in mathematics in the context of computational tools such as Computer Algebra Systems (CAS). They demonstrated in their work that taking learning styles into account in the classroom increases academic performance in linear algebra subjects and improves the process of reflection and abstraction [Craveri, and Anido \(2008\)](#).

In the field of mathematics education, AI has been successful in enhancing the understanding of more complex concepts. For example, [Singh et al. \(2021\)](#) discuss problematic aspects of teaching linear algebra, noting the lack of effective visualization tools and suggesting technology-based approaches to aid student comprehension.

Furthermore, Peng et al. (2021) discuss how to teach the Capital Asset Pricing Model (CAPM) using linear algebra and how AI can help improve the understanding of complex financial models for engineering and science students.

Thus, as shown in Figure 1, the key relationships of the research are presented, along with the studies considered from their thematic area. Technological approach and method.

### Box 1

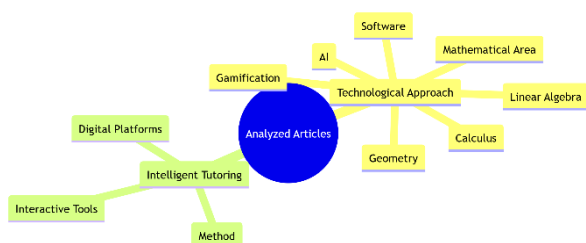


Figure 1

Conceptual Map of Similarities

### 1.1. Main characteristics of the studies

### Box 2

Table 1

Learning styles

Reference	Perspective	Methods Used	Results
Amini et al. (2024)	GOL theory for online learning with AI and fuzzy relations.	Theoretical development, n-ary fuzzy relations, t-cut.	Robust model for managing uncertain information in education.
Boyd & Vandenberghe (2018)	Applied approach to linear algebra in engineering.	Practical exercises, use of Julia/MATLAB.	Successful integration with real-world problems.
Cordero Monzón (2024)	AI in university physics/mathematics didactics.	Theoretical review.	Opportunities and ethical challenges in assessment.
Díaz Montes & Barrera Zapata (2022)	Use of digital resources in mathematics for engineering.	Systematization of teaching experience.	Best-rated virtual platforms and software.
Engelbrecht & Borba (2024)	Impact of digital technology in mathematics.	Review of trends (last 5 years).	STEAM and AI as transformative tools.
Garrido Bullón (2019)	AI as a tool for new mathematics.	Theoretical review.	Importance of fuzzy logic in computation.
Griffith (2022)	Teaching calculus with algebraic software.	Case analysis with Mathematica and Maple.	Need for complementary theory to software use.
Jančařík et al. (2023)	Online tutoring with chatbots for mathematics.	Chatbot implementation, qualitative evaluation.	Effective feedback in algebra and geometry.
Jiménez-Hernández et al. (2020)	Gamification in boolean algebra.	Experimental design (control vs. experimental group).	Greater motivation and academic performance.
Matzakos et al. (2023)	Comparison of LLMs and algebraic systems in mathematics.	Comparative study, qualitative analysis.	Pedagogical and curricular opportunities with AI.
Parra Sánchez et al. (2023)	Personalization of resources with AI for university mathematics.	Questionnaires, clustering (7 groups).	Recommendations adapted to learning styles.
Peng et al. (2021)	Teaching CAPM for STEM students.	Theoretical-practical approach without calculus.	Derives CAPM with basic tools (linear algebra, geometry).
Quiroz Rosas (2023)	AI applications in mathematics teaching.	Review of existing applications.	Tools for developing critical thinking.
Ramírez Salazar (2023)	STEAM methodology with video games for physics/mathematics.	Software development, gamification.	Motivation and practical application of mathematical modeling.
Singh et al. (2021)	Challenges in the teaching of linear algebra with technology.	Literature review (1993-2018).	Lack of effective visualization tools.
Thompson (2018)	AI and advanced technology in algebra teaching.	Analysis of educational software projects.	New forms of student-software interaction.
Val-Fernández (2023)	AI-mathematics symbiosis in secondary school.	Analysis of AI platforms, case studies.	Improvement in motivation and mathematical skills.

### 1.2. Charts of Similarities between articles

As shown in Figure 2, the similarities between the analyzed articles are listed, according to the focus of attention. Of the total number of articles analyzed, 9% correspond to studies focused on primary level, 14% on various levels, 23% on secondary level, and 55% on university level, this being of greater interest for the study.

### Box 3

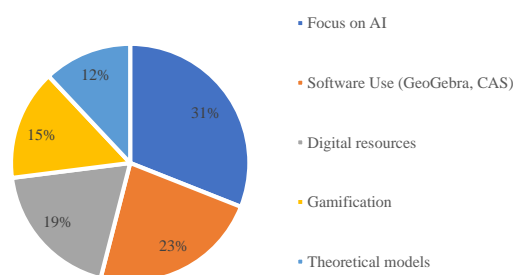


Figure 2

Similarities between articles

### 1.3. Connections between investigations

As shown in Figure 3, the connections between the different research interests can be described as follows: AI in Linear Algebra: Singh (2021) and Matzakos (2023) agree on the need for visual tools for linear algebra but differ in approach (AI vs. CAS). Amini (2024) and Thompson (2018) share the use of advanced models (fuzzy relations, hypergraphs). Gamification in STEM: Jiménez-Hernández et al. (2020) and Guzmán (2020) highlight student motivation, but the former focuses on Boolean algebra and the latter on STEM in general.

The Dominant University Level: 12 articles address higher education, especially in engineering (e.g., Boyd (2018), Parra Sánchez et al. (2023)). AI and Software are the most recurrent approaches (70% of the articles). Algebra is the mathematical area most studied with technology. University is at the most researched educational level, followed by secondary school.

## Box 4

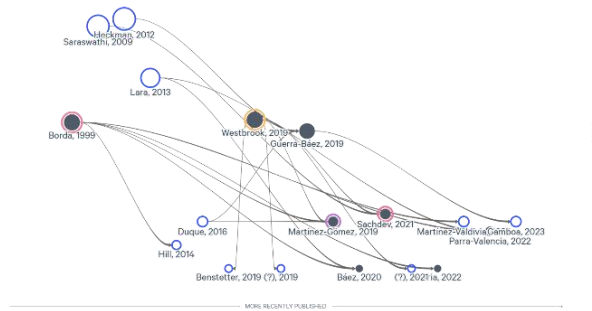


Figure 3

Research on learning styles and teaching of algebra

## 2. Studies related to innovative educational methods

Contemporary educational settings are implementing various innovative strategies, with gamification standing out as an effective method for increasing student motivation and engagement. Although its use is more common at the basic education level, its application in university contexts is also beneficial. [Bazán Perkins and Huesca Juárez \(2016\)](#) conducted an evaluation of the inclusion of gamification elements in problem-based learning (PBL) tutorial sessions. The findings revealed that, while no significant differences were observed in terms of participation or exam scores, students exposed to gamification showed greater interest and intrinsic motivation; furthermore, they demonstrated better content assimilation. This indicates that gamification could be a valuable tool for fostering learning environments without necessarily altering participation levels ([Bazán Perkins & Huesca Juárez, 2016](#)).

The following is a summary structured around three thematic axes related to the educational process in university environments: innovative methodologies, technological integration, and reflective pedagogical approaches.

### 2.1. Innovative Methodologies in University Teaching

Recent developments in the design of classroom cultures that support reflective learning have included the use of game-based instruction, positioning itself as an effective motivational strategy that can stimulate learners in intrinsic and extrinsic dimensions to help better learning.

[Jiménez-Hernández et al. \(2020\)](#) demonstrated the effectiveness of software such as MiniBool in teaching Boolean algebra, stating that this gamified application improved both motivation and performance (both of which were higher than in traditional teaching). Similarly, [Reyes Meza et al. \(2021\)](#) emphasized the need to design educational strategies according to learning styles, revealing that students with a predominantly reflective learning style performed better in mathematics, thus transforming underlying learning patterns into reflective ones by constructing new learning environments.

[Joaquim et al. \(2022\)](#) also investigated gamified smart tutoring systems in low-income Brazilian students. They found both good and bad pedagogical practices and noted that, to ensure the success of this type of tool, it is critical that the school curriculum be integrated with the system and that there be a clear intervention plan. Furthermore, they concluded that gamified systems can significantly improve math and language skills ([Joaquim et al., 2022](#)).

In contrast, the STEAM (Science, Technology, Engineering, Arts, and Mathematics) approach has been well-utilized at the university level. [Ramírez Salazar \(2023\)](#) demonstrated that incorporating art into the teaching of physics and mathematics through video games and mathematical software fosters experiential learning and transforms traditional rote learning into a more engaged and motivated approach.

Similarly, the structuring of teaching experiences, as suggested by [Sapién Aguilar et al. \(2023\)](#), allows teachers to reflect on their work and modify processes to support learning whenever appropriate. In this way, what is achieved in the classroom is essentially the student's "being-in-learning."

### 2.2. Integration of Emerging Technologies

Artificial intelligence has already revolutionized higher education, providing intelligent tutors and adaptive learning systems. [Val-Fernández \(2023\)](#) argued that AI personalizes mathematics instruction at the secondary and higher education levels, contributing positively to motivation and skills development.

Parra Sánchez et al. (2023) proposed an AI-based model of personalized learning resources to recommend university mathematics learning materials according to the Felder-Silverman learning style, and experimental results demonstrated that the recommended model could suggest appropriate learning materials.

Virtual learning has also played a significant role. Furthermore, Díaz Montes and Barrera Zapata (2022) have also highlighted that in engineering mathematics education, the application of digital educational resources with virtual platforms and video tutorials has facilitated student access, aligning with their study frequency and academic performance. Another report by Ballesteros-Ballesteros et al. (2022) points to social network-based teaching in the classroom (for example, the role of GeoGebra and mobile applications in learning linear algebra, as discussed in 2022, and collaborative tools).

Thus, models and simulators have proven to be effective means of supporting problem-solving skills under investigation within the scientific-technological approach to engineering education.

### 2.3. Reflective and Collaborative Pedagogical Approaches

This reinforces the idea that, in terms of teaching and learning, the primary transformation in the classroom for multifaceted learning and new teaching and learning models does not begin with technology, but rather with observing how we teach. This reflection on practice is central to educational innovation. Teachers must engage in self-criticism as part of the solution to reconstruct classroom dynamics (Martínez Madrigal, 2022). Moretti (2014) focused on math clubs and other forms of collaboration as support for teacher development and the documentation of reflection and shared practice.

The methodological approach (Mera Rodríguez, 2019; Martínez-Gómez, 2019) of systematizing learning experiences has been considered, demonstrating its contribution to knowledge creation through practice and improvement, focusing on educational processes.

Furthermore, it has been found that the use of gamified collaborative learning among higher education students not only improves intrinsic motivation but also learning performance, as indicated by Bazán Perkins and Huesca Juárez (2016). This study of standardized educational settings has become a key tool for improving teaching practices. Sapién Aguilar et al. (2023) provides a framework for systematization and includes the analysis of classroom work from a retrospective perspective to reveal successes and potential for further development through scaffolding.

This strategy has proven helpful in improving students' positive attitudes and, moreover, in the diversity of technological media and formats implemented for learning (Sapién Aguilar et al., 2023).

Furthermore, Martínez-Gómez (2019) examines systematization in popular education, identifying some challenges and lessons learned from practice. Martínez-Gómez (2019) highlights in her work the innovative nature of metacognitive reflection and knowledge construction through experience.

Corresponding to the above, Figure 4 shows the key relationships of the research in relation to innovative educational methods, the studies considered from their educational level, their approach, thematic area and method.

#### Box 5

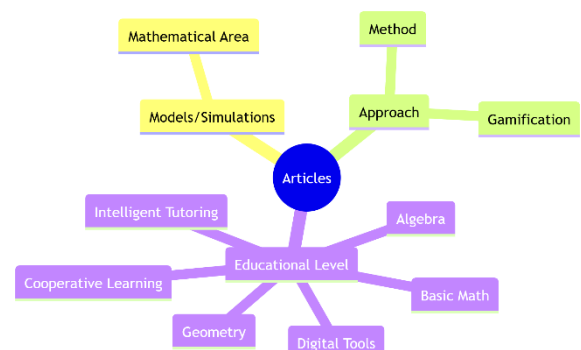


Figure 4

Conceptual Map of Key Relationships

### 2.4. Main characteristics of the studies

The following analysis in Table 2, Innovative Educational Methods, classifies the main characteristics of the articles considered in the research:

Ramírez, Moisés, González, Yeseniab, Ramírez, Federico and Pedroza, Blanca. [2025]. Systematic review of contemporary strategies in algebra teaching: Analysis of trends in the introduction of AI. Journal of Technical Education. 9[21]1-13: e3921112  
<https://doi.org/10.35429/JTE.2025.9.21.3.1.12>

## Box 6

Table 2

Innovative educational methods

Reference	Focus and Perspective	Methods Used	Results	Educational Level and Area of Study
Abramovich et al. (2013)	Alternative assessment. Educational badges.	Experimental study with intelligent tutor.	Positive impact on motivation, dependent on badge type.	Secondary/University; Educational Technology, Motivation
Ballesteros-Ballesteros et al. (2022)	Mobile technology in the classroom. Mobile devices in algebra.	Experimental design (4 Solomon groups).	Better performance with GeoGebra.	Secondary/University; Algebra, Educational Technology
Ciro (2025)	Integrating storytelling and abductive reasoning into mathematics education.	Analyzes the structure of storytelling and its connection to abductive logic.	It suggests that storytelling fosters cognitive and emotional involvement, improving mathematical understanding.	From primary to higher education. Mathematics Education.
Cordero Monzón (2024)	Responsible teaching with AI. AI in university physics/mathematics.	Theoretical review.	Opportunities and ethical challenges.	University; Physics, Mathematics, Ethics in AI
Díaz Montes & Barrera Zapata (2022)	Hybrid teaching in mathematics. Use of digital resources.	Systematization of experiences.	Higher acceptance of virtual platforms and video tutorials.	University (Engineering); Mathematics, Digital Education
Engelbrecht & Borba (2024)	Technological innovation. Digital technology in mathematics.	Systematic review.	Impact of STEAM, AI, and personalization.	All levels; Mathematics, Technology, AI
Guzmán-Rivera et al. (2020)	Innovation in STEM teaching. Gamification in STEM.	Conceptual mapping (analysis of 39 documents).	Differentiation between gamification, serious games, and game-based learning.	University; Science, Technology, Engineering, Mathematics
Jiménez-Hernández et al. (2020)	Playful learning. Gamification in boolean algebra.	Controlled experiment (control/experimental groups).	Higher motivation and performance with MiniBool.	University; Computer Science, Algebra
Joaquim et al. (2022)	AI in education for low-resource settings. Gamified intelligent tutoring.	Qualitative case study (9 months).	Improvement in language and mathematics skills.	Primary/Secondary; AI, Inclusive Education
Martínez-Gómez (2019)	Reflective and social learning. Popular education and metacognition.	Case study (Tunjuelo Pre-University).	Challenges in systematization of educational experiences.	Pre-university; Popular Education, Metacognition
Mera Rodríguez (2019)	Empowerment and educational transformation. Systematization as a research method.	Documentary review, qualitative analysis.	Knowledge generation from educational practice.	University; Pedagogy, Educational Research
Parra Sánchez et al. (2023)	Adaptability in teaching. Personalization with AI.	Questionnaires, clustering (7 groups).	Effective resource recommendation based on learning styles.	University; Mathematics, AI, Learning Styles
Reyes Meza et al. (2021)	Educational personalization. Learning styles (Honey-Alonso).	Styles test, quantitative analysis.	Reflective style predominant in mathematics.	Secondary/Pre-university; Mathematics, Educational Psychology
Sapién Aguilar et al. (2023)	Teacher reflection and continuous improvement. Systematization of teaching experiences.	Surveys, ANOVA, linear regression, K-means.	Improvement in student perception with educational scaffolding.	University (Physical Culture Sciences); Information Technologies, Higher Education
Val-Fernández (2023)	AI-education integration. AI in mathematics teaching.	Theoretical review.	Learning personalization, improvement in motivation.	Secondary/University; Mathematics, Artificial Intelligence

## 2.5. Connections between investigations

As shown in Figure 5, the connections between innovative educational methods can be described according to: AI and Intelligent Tutoring: Jiménez-García (2023) and Jančařík (2023) agree on using AI to personalize learning (chatbots, learning wheel). Sklavakis and Refanidis (2013) applies intelligent tutors in algebra and basic mathematics.

Gamification and Motivation: Bazán-Perkins (2016) and Joaquim (2022) analyze gamification in STEM, highlighting its impact on motivation and performance. Abramovich (2013) studies badges as positive reinforcement in tutored systems.

Learning Styles: Craveri, and Anido (2008) and Reyes-Meza (2021) link learning styles (Honey-Alonso) with computational tools for linear algebra. Systematization of Experiences: Sapién-Aguilar (2023) and Mera-Rodríguez (2019) propose methods for documenting and improving teaching practices in mathematics. AI and Gamification are the most frequently used approaches, especially at the university and secondary levels. Algebra is the most studied area, with tools such as GeoGebra, CAS, and chatbots. Digital Tools and Cooperative Learning are the preferred methods for innovation in teaching.

## Box 7

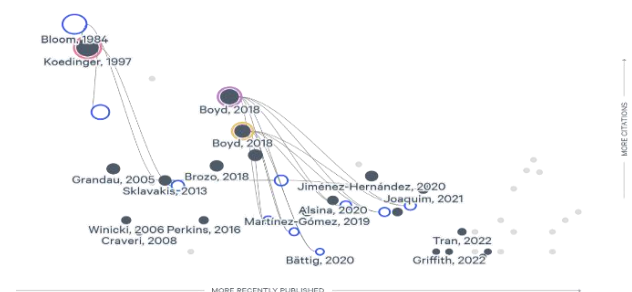


Figure 5

Research on innovative methods

## 3. Studies related to Artificial Intelligence in Education

Artificial intelligence (AI) in education has also raised new moral and practical questions. Machine-Mastromatteo points to the effects of AI on science and publishing, as well as the dangers of AI when companies refuse to be transparent and accountable for it.

Education is one of the fields where AI has been labeled a disruptive force and has been gaining popularity. By 2020, AI had become a reality, moving beyond McCarthy's initial aspirations to solve difficult problems for which no algorithm existed (e.g., machine learning, pattern recognition, big data mining; (Garrido Bullón, 2019). In education, AI has altered how learning and teaching take place, especially in subjects like mathematics and physics, where intelligent tutoring systems provide personalized support and resources that assist students in their learning process (Cordero Monzón, 2024).

Jančařík et al. (2023) analyze the use of AI chatbots as feedback in online mathematics tutoring. The authors acknowledge that appropriate feedback in this environment must be tailored to specific mathematical topics in algebra and geometry. This represents a useful step in structuring student learning for national exams (Jančařík et al., 2023).

Another online algebra problem-solving tutor, MATHESIS, was implemented by Sklavakis and Refanidis (2013), which provides formative feedback generation. We then trained a deep tracking model that encodes each skill as a mathematical expression with personalized formative feedback. "Make exactly one product on board." Azimuthal blackboard applications were used for lecturing and practicing (Sklavakis and Refanidis, 2013).

The goal of AI and education is 'more than just (already very complex) intelligent tutoring'. Zatti et al. (2022) suggest AI-based architectures and models for developing mathematical learning objects, for a clearer delivery of adaptive teaching. We call the system GenIA, and it is implemented as a programming model that can express what can be understood from school mathematics.

Finally, Parra Sánchez et al. (2023) present a generic AI approach that can be used as a black box to profile learning materials according to the student's personality type in the Felder and Silverman model and suggest the most appropriate learning materials corresponding to the student's learning.

There are also some strengths within the university for AI-based learning and teaching. Mobile applications are theoretically growing while some technical stages are being planned, as they may require a database server (Berrones Yaulema & Salgado Oviedo, 2023). Mobile devices are handling this project, which offers multiple functions and advanced features for distributing academic data through AI educational applications. This allows for different processing of this data, such as administrative processes, in other applications. Its use, like any other calculation-updating machine, is estimated in relation to a computer base for any student, which is not the software tool (device tool) that can be used as a tool to generate data and intelligent software calculations. However, there are also difficulties, such as teacher training, technological infrastructure and availability, or new evaluation systems (Cordero Monzón, 2024).

In education, AI has already proven to be a game-changer for learning certain subjects. Álvarez-Sepúlveda (2023) explores AI in history teaching, examining technical and ethical issues, but also possibilities for expanding students' historical thinking. On a different note, Flores-Vivar (2023) focuses on AI in virtual teaching and learning, reflecting on what AI offers and the technological, pedagogical, and ethical requirements it poses for education.

Data mining in education with AI has also played a role in AI and its application in education. Machín Torres (2018), for example, states that data mining can be used to predict student behavior in intelligent tutoring systems and develop more personalized recommendations. Castellani et al. (2024) further advance this view by discussing how the role of AI should be analyzed within the broader context of intelligent tutoring systems and the extent to which AI is being used to facilitate the development of new adaptive learning systems.

AI in education is very trendy these days. Jiménez-García et al. (2023) – Using Carrington's Pedagogical Wheel in AI teaching – is among the teaching and learning methods for AI. The five nodes of their methodological concept are: information and communication technologies in education, use of educational technology, design or articulation of pedagogical models, and ethics and sustainable education.

For example, such a response would involve several cycles on what it means to support AI along a cognitive theory curve, analogous to Bloom's Taxonomy, but for AI. Furthermore, it highlights the significant influence that the metacognitive-reflective factor seems to exert on the dimensions of ethics and responsibility (Jiménez-García et al., 2023).

### 3.1. Teacher Training and Interdisciplinary Collaboration

Another important aspect is teacher training to enable the use of AI. Rosignoli (2023) emphasizes the importance of training trainers, specifically those who will be trained to integrate Generative Artificial Intelligence (AI) into university teaching. This training anticipates the need for critical reflection on the introduction of these technologies in the classroom.

Furthermore, Bellettini Vela et al. (2024) highlights the need for in-service training and interdisciplinary work to mitigate institutional barriers to the implementation of AI in university teaching.

Finally, virtual learning and AI enhance autonomous learning. Suyo-Vega et al. (2021) conducted a systematic review of autonomous learning in universities and found that focus and planning are key to achieving autonomous learning, while the experience of the trainers facilitates it.

As shown in Figure 6, key relationships of studies on AI are identified, the articles analyzed from that area of application, approach, challenge, and method. The analysis presents an overview of the scope of the study.

### Box 8

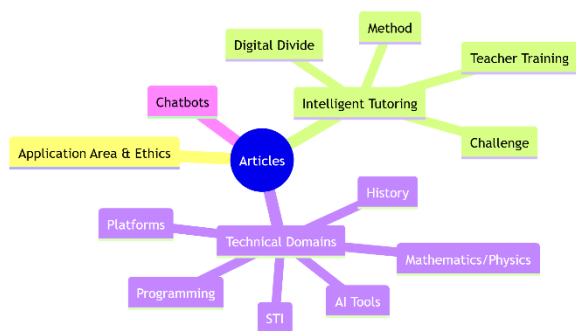


Figure 6

Key relationships in AI studies

### 3.2. Main characteristics of the studies

Table 3 below, Artificial Intelligence, presents a summary of the references highlighting their perspective, methods used, results, main focus, educational level, and relevant areas of study:

### Box 9

Table 3

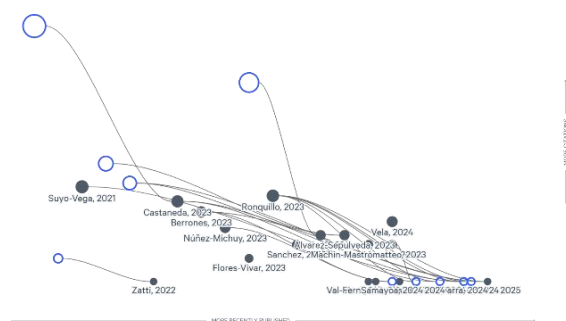
Artificial intelligence

Reference	Focus and Perspective	Methods Used	Results	Educational Level and Area of Study
Álvarez-Sepúlveda (2023)	Innovation in humanities. AI in history teaching.	Inductive method. qualitative approach.	AI enriches historical learning but requires ethical balance.	Secondary/University; History, Ethics in AI
Arias et al. (2025)	Developing mathematical thinking through the use of the Moodle platform and active learning strategies.	Experimental design. Pre- and post-testing to measure development.	The implementation of structured active learning activities via Moodle.	Secondary or Higher Education. Mathematics, Educational Technology.
Bellettini Vela et al. (2024)	Institutional adoption. AI in university teaching.	Semantic network, surveys.	Lack of teacher training and need for ethical policies.	University; Educational Policies, AI
Berrones Yaulema & Salgado Oviedo (2023)	Automation and data analysis. AI for educational improvement.	Descriptive bibliographic review.	Tools like intelligent tutors and chatbots personalize learning.	University; Educational Technology, AI
Castellani et al. (2024)	Adaptability and educational inclusion. AI in Intelligent Tutoring Systems (ITS).	Bibliographic review (BDTD, 2015-2020).	ITS with AI improve personalization and immediate feedback.	University; AI, Intelligent Tutors, Pedagogy
Cordero Monzón (2024)	Didactics with AI. AI in university physics/mathematics.	Theoretical review.	Opportunities in intelligent tutoring, with ethical and technical challenges.	University; Physics, Mathematics, AI
Flores-Vivar (2023)	Emerging technologies. Impact of AI on virtual education.	Documentary review.	AI transforms teaching but poses ethical and technical challenges.	All Levels; Pedagogy, Digital Ethics
Garrido Bullón (2019)	Theoretical bases of AI. Mathematical foundations of AI.	Historical-conceptual approach.	Mathematics is essential for the development of AI.	University; Mathematics, AI
Machín Torres (2018)	Educational data analysis. Data mining in ITS.	Theoretical modeling and applied proposal.	Data mining optimizes student modeling in ITS.	University; Data Mining, ITS
Machin-Mastroratteo (2023)	Academic integrity. AI in scientific research.	Analysis of editorial policies.	Transparency and ethics are key in the use of AI for scientific publication.	University; Ethics, Scientific Publications
Magallanes Ronquillo et al. (2023)	Responsible implementation. AI in educational innovation.	Case study, surveys, data analysis.	Tools like chatbots improve teaching and automate tasks.	University; Innovation, AI
Núñez-Michuy et al. (2023)	Adaptive teaching models. AI in pedagogy.	Systematic review (Redalyc, Scielo, Scopus, WoS).	Personalization of learning with chatbots and recommendation systems.	University; Pedagogy, AI
Parra Sánchez et al. (2023)	Adaptive learning. Personalization with AI in university mathematics.	Questionnaires, clustering (7 groups).	Effective model for recommending resources based on learning styles.	University; Mathematics, AI
Quiroz Rosas (2023)	Critical thinking with AI. AI in mathematics teaching.	Analysis of existing tools.	Recommendations for integrating AI into teaching strategies.	University; Mathematics, AI
Rosignoli (2023)	Teacher training. Generative AI in teacher training.	Theoretical framework under construction.	Need for critical reflection to integrate AI into university teaching.	University; Generative AI, Pedagogy
Suyo-Vega et al. (2021)	Learning virtualization. Autonomous learning in virtual environments.	PRISMA systematic review (Scopus, Scielo, Eric, Ebsco Host).	Teacher expertise and planning are key to student autonomy.	University; Distance Education, ICT
Tai & Hieu (2018)	Personalization in mathematics. Interaction networks in ITS for mathematics.	Analysis of data-driven models.	Generation of automated and scalable feedback.	Secondary/University; Mathematics, AI, ITS
Urquilla Castaneda (2023)	Educational innovation. AI in Education (AIEd).	Theoretical perspective.	AI helps decipher student difficulties and improves the educational experience.	University; Applied AI, Education
Val-Fernández (2023)	Personalization in mathematics. AI in secondary mathematics.	Theoretical review and practical examples.	Greater motivation and performance with adaptive tools.	University; Mathematics, AI
Zatti et al. (2022)	Human-AI interaction. AI platform for math L.Os.	Educational design research.	Promotes the collaborative construction of learning objects.	University; Mathematics, Educational Design

### 3.3. Connections between investigations

The studies that integrate the two previous research approaches are those related to artificial intelligence, as shown in Figure 7. The connections between the different studies are described as follows: AI in Higher Education: Cordero Monzón (2024) and Parra Sánchez et al. (2023) highlight the personalization of learning in mathematics/physics using AI. Bellettini (2024) analyzes institutional challenges for its implementation. Intelligent Tutoring (IT): Castellani (2024) and Machín (2018) explore IT for adapting content and providing immediate feedback. AI Tools: Zatti (2022) proposes platforms for creating learning objects. Ethics and Policies: Flores-Vivar (2023) and Machín-Mastromatteo (2023) discuss privacy, biases, and the need for regulation. Common Challenges: Teacher training (Rosignoli 2023) and the digital divide (Urquilla 2023) are recurring themes. University Domain: 70% of articles focus on higher education. Mathematics/Physics: Area most benefited by AI (e.g., STI, adaptive platforms). Chatbots and STI: Predominant methods for personalization. Ethics: Critical challenge across all approaches.

#### Box 10



**Figure 7**

Studies about AI

### Conclusions

Taken together, these investigations describe the contemporary change in classroom environments in mathematics teaching, the incorporation of different software-supported strategies and how these induce the generation of conducive learning environments, and they also underline the importance of adapting educational strategies to the specific needs of students, using innovative technologies and methodologies based on reflection and systematization.

The integration of AI, gamification, models and simulators, and the systematization of educational experiences are promising tools for improving the teaching and learning process, if students' learning styles and ethical and pedagogical needs are considered. Studies present a specific perspective focused on the student experience within this process. Thus, AI is considered to have transformed education by offering innovative tools for personalized learning, task automation, and data analysis, and these have changed how students adapt to new educational demands. However, its implementation requires addressing technical, ethical, and pedagogical challenges, as well as the ongoing training of teachers and interdisciplinary collaboration. These considerations are essential to maximizing the benefits of AI in education and meeting contemporary challenges in teaching and learning.

### Conflict of interest

The authors declare no conflict of interest. They have no known competing financial interests or personal relationships that could have influenced the article reported on herein.

### Authors' Contributions

All authors guided the research team in selecting the original theoretical framework.

### Availability of Data and Materials

The data and materials in this article are available and authorized for dissemination as appropriate.

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### Abbreviations

AI	Artificial intelligence
CAPM	Capital Asset Valuation Model
CAS	Computer Algebra Systems
ITS	Intelligent tutor system
OOS	Object oriented learning style
PBL	Problem-based learning
STEAM	Science, Technology, Engineering, Art, Mathematics

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## Anxiety, family context, and use of recreational digital media in University students during the COVID-19 contingency





### Ansiedad, contexto familiar y uso de medios digitales recreativos en estudiantes Universitarios durante la contingencia de COVID-19

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#### Abstract

**Introduction:** The COVID-19 pandemic significantly impacted the mental health of university students. Understanding the factors associated with anxiety in this population is critical for designing appropriate interventions. **Objective:** To evaluate anxiety levels and analyze their association with sociodemographic characteristics, family context, and use of entertainment technologies (e.g., video games, social media) among university students during the COVID-19 lockdown. **Method:** A total of 2,152 students (59% women; age range: 17–24 years; M = 21.34, SD = 4.30) from multiple faculties of the Universidad Autónoma de Nuevo León (UANL) completed an online survey between April and July 2020. The Generalized Anxiety Disorder scale (GAD-7) and a sociodemographic questionnaire were used. **Results:** Most students (75.6%) reported no anxiety symptoms. However, 20.9% experienced mild anxiety, 2.8% moderate, and 0.7% severe. Living in urban areas (OR = 0.821,  $p < .01$ ), having a stable family income (OR = 0.725,  $p < .001$ ), and living with parents (OR = 0.750,  $p = .016$ ) were protective factors. Having a close relative or acquaintance infected with COVID-19 was a risk factor (OR = 3.009,  $p < .001$ ). Watching daily news and working from home were positively associated with anxiety levels ( $p < .001$ ), whereas the use of video games and social media were negatively associated ( $p < .001$ ). **Conclusions:** Anxiety levels were related to economic, family, and media exposure factors. Entertainment technologies such as video games and social media may act as protective factors during confinement. It is essential to monitor students' mental health in public health emergency contexts.

#### Resumen


**Introducción:** La pandemia por COVID-19 afectó significativamente la salud mental de los estudiantes universitarios. Comprender los factores asociados a la ansiedad en esta población es clave para diseñar intervenciones adecuadas. **Objetivo:** Evaluar los niveles de ansiedad y analizar su asociación con características sociodemográficas, el contexto familiar y el uso de tecnologías de entretenimiento (por ejemplo, videojuegos, redes sociales) en estudiantes universitarios durante el confinamiento por COVID-19. **Método:** Un total de 2,152 estudiantes (59% mujeres; rango de edad: 17–24 años; M = 21.34, DE = 4.30) de diversas facultades de la Universidad Autónoma de Nuevo León (UANL) respondieron una encuesta en línea entre abril y julio de 2020. Se empleó la Escala de Trastorno de Ansiedad Generalizada (GAD-7) y un cuestionario sociodemográfico. **Resultados:** El 75.6% de los estudiantes no presentó síntomas de ansiedad. El 20.9% reportó ansiedad leve, el 2.8% moderada y el 0.7% severa. Vivir en zonas urbanas (OR = 0.821,  $p < .01$ ), tener ingresos familiares estables (OR = 0.725,  $p < .001$ ) y vivir con los padres (OR = 0.750,  $p = .016$ ) fueron factores protectores. Tener un familiar o conocido infectado por COVID-19 fue un factor de riesgo (OR = 3.009,  $p < .001$ ). Ver noticias diarias y hacer home office se asociaron positivamente con los niveles de ansiedad ( $p < .001$ ), mientras que el uso de videojuegos y redes sociales se relacionó negativamente ( $p < .001$ ). **Conclusiones:** La ansiedad se relacionó con factores económicos, familiares y de exposición mediática. Las tecnologías de entretenimiento como los videojuegos y redes sociales podrían ser factores protectores durante el confinamiento. Es fundamental monitorear la salud mental de los estudiantes en contextos de emergencia sanitaria.

Anxiety, Family Context, and Use of Recreational Digital Media in University Students During the COVID-19 Contingency

Objectives	Methodology	Contribution
		

Mental health; Coping strategies; Lockdown effects

Ansiedad, contexto familiar y uso de medios digitales recreativos en estudiantes Universitarios durante la contingencia de COVID-19

Objetivos	Metodología	Contribución
		

Salud mental; Estrategias de afrontamiento; Efectos del confinamiento

**Area:** Advocacy and attention to national problems

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## Introduction

The COVID-19 pandemic caused an unprecedented disruption in the academic and social life of university students. Studies conducted in various countries have documented notable increases in the prevalence of anxiety during the initial months of lockdown (Brooks et al., 2020; Cao et al., 2020). In a recent review with more than two million participants, Delpino et al. (2022) noted that university students represent one of the age groups with the greatest emotional vulnerability, particularly when economic uncertainty and overexposure to alarming news converge.

Regarding risk and protective factors for anxiety during the pandemic, the literature has identified multiple factors associated with the emergence of anxiety symptoms in young adults: the loss of family income (Martínez et al., 2021), prolonged social isolation (Son et al., 2020), and the presence of COVID-19 cases in one's close circle (Saddik et al., 2020). In contrast, family support and intergenerational cohabitation appear to function as buffers against psychological distress (Khoshaim et al., 2020).

These findings are partially explained by Lazarus and Folkman's (1984) stress and coping theory, which posits that cognitive appraisal of threat and the availability of support resources modulate the emotional response. Lockdown was also marked by intensive use of recreational digital media. In 2021, the Mexican population reported a 35% increase in time spent on social networks, video games, and streaming platforms (Statista, 2021). Various studies have explored the potential of these activities as coping strategies: moderate consumption of action video games has been associated with improvements in emotional regulation and positive distraction (Przybylski & Weinstein, 2019), while virtual social interaction can mitigate feelings of loneliness (Allen et al., 2014). However, Latin American research cautions that any protective effect depends on the type of content, the motivation for use, and the duration of sessions (Farfano et al., 2022; Pontes et al., 2019).

With respect to the knowledge gap in the Mexican context, the Health Ministry (Secretaría de Salud, 2021) reported that up to 30% of surveyed university students during the critical phase of the pandemic exhibited clinically relevant anxiety symptoms.

Nevertheless, most studies have focused on populations in the central region of the country, use small samples, or do not distinguish between different types of digital media. Furthermore, it is unknown how variables such as area of residence (urban vs. rural) or family economic stability interact with digital entertainment use and anxiety in students from large public institutions.

This gap is relevant considering that Mexico was one of the countries most affected in terms of health impact and structural inequality in access to mental health services during the emergency (Escudero et al., 2020).

The Universidad Autónoma de Nuevo León (UANL) provides an ideal setting to examine these phenomena given its diverse student body, both socioeconomically and in fields of study, and its location in northern Mexico, where the pandemic's economic impact had particular nuances. Understanding the risk and protective factors in this context can provide evidence to design psychosocial interventions adapted to the regional reality. Based on the above, the aim of this study was to analyze anxiety levels in university students during the COVID-19 lockdown and examine their association with sociodemographic factors, family conditions, and the use of recreational digital media (video games, social networks, and audiovisual consumption). The following research questions were posed:

- What is the prevalence of anxiety (mild, moderate, and severe) in the studied sample?
- Which sociodemographic and family variables are significantly associated with anxiety levels?
- Is the use of recreational digital media negatively or positively related to self-reported anxiety?

Addressing these questions will clarify the role of leisure technology resources as potential modulators of emotional well-being and will offer guidelines for evidence-based university support strategies. In this sense, Duan and Zhu (2020) emphasize that during health crises, the design and implementation of contextually adapted, scientifically grounded psychological interventions is a priority to mitigate the emotional impact on vulnerable populations.

## Methodology

### Study Design

A quantitative, observational ex post facto study with a cross-sectional, correlational design was conducted. No variables were manipulated, and associations between sociodemographic, family, technology use variables and anxiety levels were analyzed in their natural context during the COVID-19 lockdown.

### Participants

The sample consisted of 2,152 university students (59% women and 41% men) between 17 and 24 years old ( $M = 21.34$ ,  $SD = 4.30$ ), enrolled in various faculties of the Universidad Autónoma de Nuevo León (UANL), Mexico. Participation was voluntary, and data confidentiality was ensured.

The sampling strategy was cluster sampling: faculties were selected as sampling units and the questionnaires were distributed to student groups via institutional and academic channels. Because the survey link was disseminated through faculty email lists and official social media, the open call nature made it impossible to precisely quantify the total number of students reached.

### Procedure

Data collection took place between April 15 and July 31, 2020, a period that coincided with the mandatory lockdown declared in the state of Nuevo León. The questionnaire was hosted on the QuestionPro® platform, configured to accept only one response per IP address and to record the submission date and time to avoid duplicates. The link to the questionnaire was distributed via institutional email lists targeting active students of each faculty, as well as through the university's and student societies' official social media channels (Facebook®, WhatsApp®, Twitter®).

The first page of the questionnaire included the study objectives, an assurance of anonymity and confidentiality, a statement of voluntary participation, and the option to abandon the survey at any time without consequences. Only participants who checked the "I agree to participate" box were able to continue.

## Inclusion Criteria

Being enrolled in an undergraduate program at UANL during the 2020-1 academic year; Being 17–24 years old; Answering all items of the GAD-7; Fifty-six incomplete records were discarded.

## Instruments

Sociodemographic and contextual questionnaire (ad hoc):

This questionnaire included closed-ended questions about: Sex, age, municipality, and area of residence (urban/rural); Family cohabitation (living with parents or not) and family income stability (yes/no); Close contact with COVID-19 cases (yes/no), remote work status, and daily news exposure; Use of recreational digital media: social networks, video games, and audiovisual content. Each activity was recorded by weekly frequency (0 = never, 1 = 1–2 days, 2 = 3–4 days, 3 = 5–7 days).

Generalized Anxiety Disorder Scale (GAD-7):

We used the Spanish version of the GAD-7 developed by Spitzer et al. (1999), validated by Toussaint et al. (2020). This scale consists of 7 items with a 4-point Likert scale (0 = "not at all", 3 = "nearly every day"), for a total score range of 0 to 21. It has high internal reliability ( $\alpha = .91$ ). The cut-off points used were: 0–4 = No anxiety; 5–9 = Mild anxiety; 10–14 = Moderate anxiety; 15–21 = Severe anxiety.

## Data Analysis

Statistical analysis was performed using SPSS v.22.0. First, descriptive analyses were carried out, and normality of the variables was checked using the Kolmogorov-Smirnov test and homogeneity of variances with Levene's test. Because the variables did not meet normality assumptions, non-parametric tests (Mann-Whitney U and Kruskal-Wallis) were chosen to compare anxiety levels according to sociodemographic characteristics.

The mean completion time was 8 min 30 s ( $SD = 2$  min 05 s), indicating adequate attention to the items.

Subsequently, ordinal logistic regression analyses were conducted to determine factors significantly associated with anxiety levels, and Spearman correlation analyses were performed between pandemic-related factors and anxiety levels. A significance level of  $p < .05$  was considered.

### Ethical Considerations

The study was approved by the Ethics Committee of the Faculty of Sports Organization at UANL (No. REPRIN-FOD-137) and was conducted in accordance with the principles of the Declaration of Helsinki (2013) and the ethical standards of the American Psychological Association (APA).

### Results

The sample was composed of 2,152 university students from UANL. Of the total, 59% were women ( $n = 1,269$ ) and 41% men ( $n = 883$ ). The mean age was 21.34 years ( $SD = 4.30$ ), with a range from 17 to 24 years. 93% resided in urban areas, and 95.14% lived with their parents. Additionally, 51.15% reported instability in family income, and only 0.6% indicated having relatives or acquaintances infected with COVID-19.

Table 1 displays the reported anxiety levels measured by the GAD-7. The majority of participants (75.6%) had no anxiety symptoms. 20.9% reported mild anxiety, 2.8% moderate anxiety, and 0.7% severe anxiety.

### Box 1

**Table 1**

Anxiety levels in university students ( $n = 2,152$ )

Anxiety Level	N	%
Normal	1635	75.6
Mild	449	20.9
Moderate	53	2.8
Severe	15	.7

*Note: Self-authored table*

Subsequently, Table 2 presents the descriptive statistics for the items of the Generalized Anxiety Disorder scale (GAD-7), including skewness and kurtosis values

### Box 2

**Table 2**

Estadísticos descriptivos de los ítems según la Escala de Trastorno de Ansiedad Generalizada (GAD-7)

ítem	Asimetría	Curtosis
1. Felt nervous, anxious, or on edge	-.74	-.54
2. Not being able to stop or control worrying	-.60	-.60
3. Worrying too much about different things	-.97	-.96
4. Trouble relaxing	-.55	-.62
5. Being so restless that it is hard to sit still	-.59	-.44
6. Becoming easily annoyed or irritable	-.51	-.52
7. Feeling afraid as if something awful might happen	-.60	-.57

*Note: Self-authored table*

An example item from this scale is: "I felt so restless that I could not sit still." The questions were answered on a four-point Likert scale, where 0 indicates "not at all" and 3 "nearly every day."

As for the questionnaire on pandemic-related stressors, an example item was: "In the last few weeks, have you felt worried about your economic situation?" These questions were also answered on a Likert scale, where 0 indicated "strongly disagree" and 7 "strongly agree."

Normality of the variables was evaluated with the Kolmogorov-Smirnov test and homogeneity of variances with Levene's test. Since several variables did not meet the normality assumptions, non-parametric tests were used.

This methodological decision provided more robust results appropriate to the context of the study, considering the sample characteristics and the emergency situation in which the data were collected.

### Univariate analysis: Variables associated with anxiety levels

Mann-Whitney U and Kruskal-Wallis tests were performed to compare anxiety levels according to sociodemographic and family variables (see Table 3 in Annex 1).

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The results showed that living in urban areas, compared to rural areas, was a protective factor against developing anxiety among participants (OR = 0.821, 95% CI = 0.708–0.923).

In addition, having stable family income (OR = 0.725, 95% CI = 0.643–0.815) and living with parents (OR = 0.750, 95% CI = 0.595–0.955) were also favorable factors against anxiety. In contrast, having a relative or acquaintance infected with COVID-19 was a risk factor (OR = 3.009, 95% CI = 2.377–3.804).

### Correlation between pandemic-related factors and anxiety

Spearman's correlation coefficient was used to explore the relationship between pandemic-related contextual variables and anxiety levels. Table 4 shows the significant correlations.

#### Box 3

**Table 3**

Correlations between pandemic-related factors and anxiety

Facto	Nivel de ansiedad	
	<i>r</i>	<i>P</i>
Concern about finances	.328	< .001
Concern about academic delays	.316	< .001
Social media use	-.130	< .001
Video game use	-.153	< .001
Remote work (home office)	.326	< .001
Watching COVID-19 news daily	.320	< .001
Watching movies or series	-.145	< .001

Note. *r*: Spearman correlation coefficient

The present study examined anxiety levels in university students during the COVID-19 lockdown, as well as their association with sociodemographic factors, family context, and the use of recreational digital media such as social networks, video games, and audiovisual content.

The results showed that approximately one in four students reported anxiety symptoms, with the majority being mild in intensity. These findings coincide with international reviews indicating a widespread increase in anxiety in university populations during the pandemic, although predominantly mild cases (Delpino et al., 2022; Liyanage et al., 2021; Magson et al., 2021).

They are also consistent with studies in other regions of Latin America (Bautista et al., 2023; Martínez et al., 2021; Medina & Ródenas, 2022) that identified high levels of anxiety, stress, and sleep disturbances in students in northwestern Mexico during the same critical confinement period.

Living in an urban residence, having stable family income, and cohabiting with parents were associated with lower anxiety levels. These findings reinforce evidence linking the availability of material resources and family support with greater emotional coping during health emergencies (Khoshaim et al., 2020; Son et al., 2020). The proximity of a confirmed case of COVID-19, by contrast, multiplied the risk of anxiety, replicating results obtained in university samples from the Middle East and Asia (Nakhostin-Ansari et al., 2020; Saddik et al., 2020). This effect can be explained by perceived stress theory: direct exposure increases threat appraisal and, consequently, the anxious response (Brooks et al., 2020).

Importantly, having a close relative or acquaintance infected with COVID-19 was identified as a risk factor that significantly increased the likelihood of experiencing anxiety symptoms. This pattern has also been observed in other countries and regions, where close contact with the disease generates greater perceived threat, anticipatory distress, and fear of contagion (Nakhostin-Ansari et al., 2020; Saddik et al., 2020).

One of the most relevant contributions of this study was the observation of a negative correlation between the use of recreational digital media—such as video games, social networks, and watching movies or series—and anxiety levels. These results align with recent research that has documented the potential regulatory effect of digital leisure on psychological distress during confinement or acute stress situations (Abi-Jaoude et al., 2020; Bossenbroek et al., 2020; Casado & Sánchez, 2022). It is possible that these forms of digital entertainment operated as distraction mechanisms or informal emotional coping strategies in the studied population. However, the literature warns that the benefit depends on the type of activity and screen time (Twenge & Joiner, 2020); future work should disaggregate these components to clarify their differential effect.

Unlike several studies that report greater vulnerability among women (Alsahhe et al., 2020; Moreno et al., 2019), no significant differences by sex were found. One possible explanation is the high proportion of students living with their families, a condition that could buffer gender gaps in perceived social support. Regarding the academic context, descriptive analyses suggested higher anxiety levels in faculties with a considerable practical component (for example, the Sports Organization faculty), which coincides with research highlighting the importance of physical activity and in-person instruction for the well-being of this group (Allen et al., 2014). Although this relationship was not confirmed in the multivariate model, it represents a promising line of inquiry for program-specific interventions.

In summary, the study provides contextualized evidence on factors associated with anxiety in Mexican university students and underscores the possible modulating role of digital leisure during prolonged confinement.

### Limitations and Future Research Directions

This study has several limitations that should be considered when interpreting the results. First, a cross-sectional design was used, which prevents establishing causal relationships between the variables analyzed. Although significant associations were identified between certain factors and anxiety levels, it is not possible to determine the direction or temporality of these effects. The lack of longitudinal follow-up makes it impossible to observe the evolution of anxiety at different stages of the pandemic or after the return to in-person classes.

Second, although the use of recreational digital media such as video games, social media, and audiovisual content was addressed, key variables were not explored, such as frequency, duration, type of content, or motivations for use, which limits the depth of the analysis. Future studies could incorporate specific instruments to evaluate these aspects and thus clarify their role as risk or protective factors for anxiety.

Lastly, although descriptive differences were identified between academic faculties, these were not included in the multivariate models, so any conclusion in that regard must be taken with caution.

Future research could explore in greater depth how curricular characteristics (in-person attendance, practical workload, academic demands) affect the emotional health of students. It is suggested that future studies address these limitations through longitudinal designs, probabilistic sampling, more specific measurements of digital technology use, and analyses by academic and sociodemographic subgroups. This approach would generate more robust and contextualized evidence for designing preventive or emotional support interventions in the university setting.

### Conclusions

The results of this study show that during the COVID-19 lockdown, the majority of UANL university students did not exhibit clinically significant anxiety symptoms. However, a considerable percentage (24.4%) reported mild, moderate, or severe anxiety levels, highlighting the need for preventive psychological care in health emergency contexts.

The factors associated with a lower likelihood of exhibiting anxiety symptoms were residing in urban areas, having stable family income, and living with one's parents. In contrast, having had a family member or acquaintance infected with COVID-19 was significantly associated with a higher risk of anxiety, confirming the relevance of contextual and family factors in the emotional health of students. Additionally, a negative relationship was observed between the use of recreational digital media (such as video games, social media, and audiovisual content) and anxiety levels. These findings suggest that such activities may have served an emotion regulation function during confinement, although this study did not explore the type, frequency, or specific context of use. Taken together, these results allow for a better understanding of the factors associated with anxiety in the university population during periods of social isolation, and offer key elements for designing targeted institutional psychological support strategies.

### Declarations

### Conflict of interest

The authors declare no interest conflict. They have no known competing financial interests or personal relationships that could have appeared to influence the article reported in this article.

Medina-Villanueva, Samantha, Ródenas-Cuenca, Luis Tomas, Ponce-Carbajal, Nancy and Vanegas-Farfano, Minerva Thalia. [2025]. Anxiety, family context, and use of recreational digital media in University students during the COVID-19 contingency. *Journal of Technical Education*, 9[21]1-9: e4921109  
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## Article

**Author contribution**

*Samantha Medina Villanueva.* Conceptualization: Formulation or evolution of the general objectives and goals of the research.

*Luis Rodenas Cuenca.* Supervision: General direction and leadership of the research group or supervision of the work performed.

*Nancy Ponce Carbajal.* Review and editing: Critical review, comments and editing of the manuscript.

*Minerva Thalia Juno Venegas Farfano.* Validation: Verification and confirmation of results, methods and analysis.

**Availability of data and materials**

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## Annexes 1

## Box 4

Table 4

Ordinal logistic regression analysis of factors associated with anxiety

Factor	N	SD	OR	P	OR (95% CI)
Area of residence					
Urban	2001	.060	.821	.003	(.708, .923)
Rural	151	-	-	-	-
Stable family income					
Yes	1051	.062	.725	<.001	(.643, .815)
No	1101	-	-	-	-
Living with parents					
Yes	2047	.121	.750	.016	(.595, .955)
No	105	-	-	-	-
Close relative with COVID-19					
Yes	13	.123	3.009	<.001	(2.377, 3.804)
No	2139	-	-	-	-

Note. SD: Standard deviation; OR: odds ratio, IC: Confidence interval

## Optimization of the vocational choice process through a digital tool

### Optimización del proceso de elección vocacional mediante una herramienta informática

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#### Abstract

Since the last decade of the 20th century, the technological boom, linked to “super- globalization,” has broadened the variety of academic and professional fields available to meet needs ranging from agricultural and industrial production to technological and educational innovation across societies worldwide. However, the “traditional” pedagogical model has limited vocational guidance for adolescents and young people, failing to reflect today’s context, where technological tools are part of daily life in much of the world. Consequently, this project arises from the need to optimize the integration of new technologies into the educational system, enabling young people to focus their skills, attitudes, and aptitudes on the most suitable academic areas according to their personal qualities. At the same time, it seeks to strengthen student enrollment in strategically important fields of study demanded by today’s world.

#### Resumen

A partir de la última década del siglo XX, el “boom” tecnológico ligado a la “super- globalización” ha incrementado la variedad de carreras de estudio que permita satisfacer, desde las necesidades derivadas en la producción agrícola e industrial, hasta las relacionadas con la innovación tecnológica y didáctica en las sociedades del mundo, sin embargo, el modelo pedagógico “tradicional” ha propiciado que la orientación vocacional de los adolescentes y jóvenes sea limitada en relación al contexto de una actualidad, donde las herramientas tecnológicas forman parte de la vida cotidiana de gran parte de las sociedades del mundo. En consecuencia, el presente proyecto, parte de la necesidad de la optimización de las nuevas tecnologías al sistema pedagógico que permita a los jóvenes enfocar sus habilidades, actitudes y aptitudes a los ámbitos académicos más oportunos, de acuerdo a sus cualidades y que, a su vez, permita el incremento de alumnado para los ámbitos de estudios estratégicos que exige el mundo actual.

Optimization of the vocational choice process through a digital tool		
Objectives	Methodology	Contribution
To support high school students with university aspirations in making informed career choices through the development of a digital tool that facilitates the identification of their interests and aptitudes.	The Technological University of San Juan del Río, through its Mechatronics Division, has promoted the development of the project Optimization of the Vocational Choice Process through a Digital Tool.	The expected results of the pilot phase will provide valuable insights into the relationship between vocational profiles and career choices, helping reduce dropout rates and improve student satisfaction. Additionally, the tool offers added value by delivering analytical data that supports timely academic and administrative decision-making.

Optimización del proceso de elección vocacional mediante una herramienta informática		
Objetivos	Metodología	Contribución
Ayudar a los estudiantes de secundaria con aspiraciones universitarias a tomar decisiones informadas sobre su carrera profesional mediante el desarrollo de una herramienta digital que facilite la identificación de sus intereses y aptitudes.	La Universidad Tecnológica de San Juan del Río, a través de su División de Mecatrónica, ha promovido el desarrollo del proyecto Optimización del proceso de elección vocacional mediante una herramienta digital.	Los resultados esperados de la fase piloto proporcionarán información valiosa sobre la relación entre los perfiles profesionales y las elecciones de carrera, lo que ayudará a reducir las tasas de abandono escolar y a mejorar la satisfacción de los estudiantes. Además, la herramienta ofrece un valor añadido al proporcionar datos analíticos que respaldan la toma de decisiones académicas y administrativas oportunas.

**Vocational guidance, technological tools, pedagogical model, optimization of new technologies, strategic studies.**

**Orientación vocacional, herramientas tecnológicas, modelo pedagógico, optimización de las nuevas tecnologías, estudios estratégicos**

**Area:** Promotion of frontier research and basic science in all fields of knowledge

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## Introduction

Choosing a career is one of the most significant decisions in a young person's life. Ideally, this process should be based on self-knowledge—aptitudes, interests, and values unique to each individual.

However, a lack of information, limited guidance, and external factors such as social pressure often hinder adolescents from making suitable vocational choices. This challenge is exacerbated by internal conflicts, as these decisions usually take place during adolescence—a stage marked by transition and vulnerability.

The concept of adolescence—historically recent—has evolved, particularly since the late 20th century. Today, it is often described as a “problematic” period characterized by uncertainty and fear when making decisions (Ducca-Cisneros, 2018, p.130). In addition to biological and psychological changes, adolescents also experience what López Bonelli (2003) calls rupture and mutation, both of which play a significant role in vocational choice.

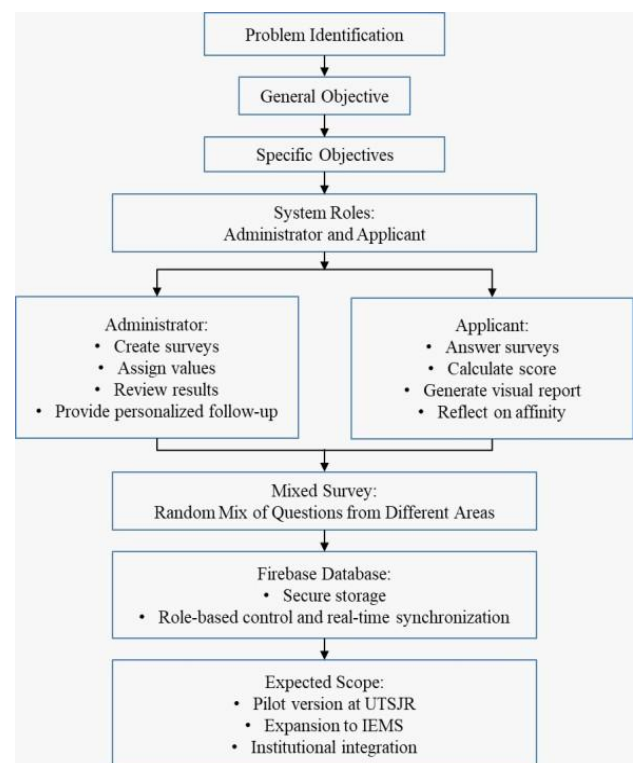
Rupture refers to “letting go of something,” either from the past or potential future, leading to indecision or the illusion of frequently changing career paths. Mutation refers to shifts in personal interests over time (López Bonelli, 2003, pp. 35–36).

Thus, vocational decision-making is often obstructed by both internal changes (biological, psychological, rupture, and mutation) and external pressures (social expectations, misinformation, lack of guidance).

Even beyond these challenges, young people fear that their career choice will not only determine their future profession but also shape their lifestyle (Niño Lara & Miranda Jaramillo, 2012, p.14). As vocational decisions become part of personal identity, adolescents often feel overwhelmed, lacking the emotional maturity to resolve such conflicts effectively (Niño Lara & Miranda Jaramillo, 2012, pp.14–15). Only once adolescents manage to overcome internal and external conflicts, assume responsibility for themselves and their future, and navigate the transitional stage of adolescence can they make sound vocational decisions (Niño Lara & Miranda Jaramillo, 2012, p.16).

## Methodology

### Box 1



**Figure 1**  
Methodology Diagram

### Problem Identification

In response to the demands of today's professional world, vocational guidance has become essential. To frame it properly, we must understand the concept of guidance within the pedagogical and didactic context. Guidance should be conceived as a process embedded within the social, cultural, and economic environment (Castañeda Cantillo & Niño Rojas, 2005, p.146).

Historically, the Vocational Bureau was founded in 1908, and Frank Parsons' Choosing a Vocation (1909) introduced the term “vocational guidance” (Castañeda Cantillo & Niño Rojas, 2005, p.148).

Yet today, the educational system continues to place young people at a crossroads when it comes to choosing a career path. Guidance generally involves three types of interventions: psychological, pedagogical, and sociological (Ducca-Cisneros, 2018, pp.127–128). Unfortunately, in many regions of Mexico, these methods have become outdated and fail to meet the current needs of young people.

Our methodology combines pedagogical guidance principles with digital technologies. Using Firebase for secure data management, the proposal aligns with [Castañeda Cantillo & Niño Rojas \(2005\)](#), who argue that vocational guidance must be a systemic process, integrated into the aspirant's context. The aim is to transform the traditional approach into a more effective, adaptive, and user-centered process with institutional application potential across educational levels. This development represents a step forward in integrating technology into educational processes, promoting equity in access to vocational support tools, and strengthening alignment between aspirants' profiles and the strategic needs of the labor market.

### General Objective

To support high school students with university aspirations in making informed career choices through the development of a digital tool that facilitates the identification of their interests and aptitudes.

### Specific Objectives

- Design and develop a digital application that allows students to take vocational surveys in a dynamic, accessible, and intuitive way.
- Implement an automated evaluation system that delivers results based on personal affinities and interests.
- Provide students with precise feedback on their vocational profile and related career options.
- Validate the tool through real user testing for future improvements and scalability.
- Create a database to store responses and trends for analysis by teachers and educational counselors.

### Project Development Proposal

The Technological University of San Juan del Río, through its Mechatronics Division, has promoted the development of the project Optimization of the Vocational Choice Process through a Digital Tool.

### Project Functionality

The project aims to provide an efficient digital solution to guide young people in their vocational choice. A mobile application was developed to administer, complete, and evaluate vocational surveys in a personalized and dynamic way, using cloud-based architecture and modern technologies.

### User Roles

The system has two main user roles:

**Administrator:** Creates vocational surveys with customizable questions and answers, assigns numerical values to measure affinity, and analyzes user results. Administrators can track each student's progress, enabling personalized follow-up.

**Student User:** Accesses surveys, answers multiple-choice questions, and receives personalized reports with visual charts summarizing affinities for different academic fields.

**Administrator.** The administrator uses a specialized interface to create new vocational surveys. Each survey can include a variable number of questions with multiple possible answers. Every answer is assigned a numerical value representing the student's level of affinity with a specific professional area. This flexibility lets the administrator tailor surveys to different vocational categories, depth levels, or specific perspectives. In addition, the administrator can review the results of surveys completed by students. The system organizes information by user, making it possible to see which surveys each person has taken, which answers they selected, and the total score obtained in each area. This functionality supports more personalized follow-up throughout the guidance process and enables informed decision-making based on the students' vocational interests.

**Student user.** The applicant accesses a section where all available surveys are listed. After choosing a survey, they are presented with a series of multiple-choice questions. As the student selects answers, the system records the associated values and, upon completion, calculates a total score that reflects their affinity with different vocational areas.

Once the survey is submitted, the system stores the responses in the database and generates a personalized visual report indicating the scores by category or suggested degree program. This report is presented clearly and intuitively through bar charts and per-survey summaries, making it easier for the student to interpret their results and reflect on their preferences.

### Mixed Survey Feature

The system can generate “mixed surveys” by combining questions from multiple surveys, offering a more comprehensive evaluation of the student’s vocational profile.

### Base de Datos Firebase

All information is managed through Firebase, a cloud-based database platform that securely stores user data, enforces role-based access control, and maintains real-time synchronization across connected devices. Firebase security rules ensure that applicants can view only their own responses, while administrators can access all information for management and oversight purposes.

### Results

The digital tool developed reached a fully functional stage and was officially presented to the academic authorities of the Technological University of San Juan del Río (UTSJR). The reception was positive, with particular emphasis on its potential as a support resource for institutional vocational guidance processes.

As a result of the preliminary evaluation, the Academic Secretary authorized the implementation of a pilot phase with the next generation of applicants. In this stage, the use of the application will be integrated into the admissions process, with the digital vocational survey established as the first activity. This mechanism will allow each applicant to obtain an individual profile of professional affinity before choosing a degree program. The system will provide users with personalized feedback based on the analysis of their responses, showing areas of interest and possible related academic paths. In this way, future students will be able to reinforce—or reconsider—their career choice in an informed manner, increasing consistency between their personal interests and the program they select.

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From the institutional perspective, the tool will provide early indicators of vocational affinity, enabling the university to promptly identify applicants with low correspondence between their profile and chosen degree. This information will facilitate the planning of orientation and retention strategies, contributing to greater student satisfaction, better academic performance, and higher program completion rates.

Looking ahead, the tool is expected to expand into upper secondary education institutions (IEMS) to broaden its coverage and strengthen career choice processes at earlier stages. Furthermore, its integration with institutional vocational guidance systems is envisioned, enabling the generation of statistical analyses and consolidated reports on applicant profiles. This integration will create a valuable source of information for academic decision-making and educational management.

### Conclusions

The development of the digital tool for optimizing vocational choice demonstrated the feasibility of integrating technological solutions into professional guidance processes. Its implementation establishes a functional model capable of analyzing individual interests and aptitudes, generating personalized results, and producing clear, easy-to-interpret visual reports. Institutional acceptance and approval for pilot application reflect the project’s relevance and its alignment with the continuous improvement strategies of the Technological University of San Juan del Río. This initiative represents a significant step toward the digitalization of admissions and vocational guidance processes, strengthening informed decision-making among applicants.

The expected results of the pilot phase will provide valuable insights into the relationship between vocational profiles and career choices, helping reduce dropout rates and improve student satisfaction. Additionally, the tool offers added value by delivering analytical data that supports timely academic and administrative decision-making.

In the long term, the application has the potential to scale into an inter-institutional environment, integrating with vocational guidance systems across other Upper Secondary Education Institutions (IEMS).

Santos-Osorio, René, Rincón-López, Reyna Andrea and López-Angeles, Dora Lilia. [2025]. Optimization of the vocational choice process through a digital tool. *Journal of Technical Education*. 9[21]1-5: e5921105.

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This expansion would enable the creation of a consolidated database that supports educational research and evidence-based decision-making.

The developed tool thus makes an innovative technological contribution to strengthening vocational guidance, linking software engineering with educational management, and promoting a more conscious, informed, and interest-driven career choice for each applicant.





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
## Thinking about how we train those who research education and human development





## Pensar cómo formamos a quienes investigan en educación y el desarrollo humano

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## Abstract




The way researchers in education are trained urgently needs to change. It's not enough to simply teach methods or adhere to rigid frameworks; research involves understanding the world, questioning, and seeking answers that give meaning to real life. Technological, sociocultural, and political-economic changes have transformed not only how we learn but also how we produce knowledge. Educational research training must respond to this context. Topics such as artificial intelligence, climate change, mental health, and cultural diversity are part of the present and directly impact human development. Incorporating them will allow students to connect with real-world problems and achieve socially relevant solutions. Furthermore, educational research is enriched when it engages with other disciplines and when it moves beyond the classroom to work with individuals and communities. Training researchers requires more humane, collaborative, and critical practices capable of generating relevant and transformative knowledge.

## Resumen

El modo en que se forma a quienes investigan en educación necesita ser cambiada con urgencia. No basta con instruir métodos o alcanzar esquemas rígidos, investigar involucra comprender el mundo, cuestionarnos y buscar esas respuestas que le den sentido a la vida real. Esos cambios tecnológicos, socioculturales y político-económicos, han transformado no solo la forma de aprender sino de producir el conocer, la formación en la investigación educativa debe responder al contexto. Tópicos como la inteligencia artificial, el cambio climático, la salud mental y la diversidad cultural forman parte del presente e impactan directamente en el desarrollo humano. Incorporarlos permitirá enlazar a los estudiantes con problemas reales y alcanzar soluciones con sentido social. Conjuntamente, la investigación educativa se enriquece cuando participa con otras disciplinas y cuando sale del aula al trabajar con las personas y las comunidades. Formar investigadores exige prácticas más humanas, colaborativas y críticas, capaces de generar conocimiento relevante y transformador.

Thinking about how we train those who research education and human development		
Objectives	Methodology	Contribution
 <p>Objective: Recognize how the three axes of analysis are articulated to reconstruct the links of educational research.</p>	 <p>Documentary research is developed under a qualitative approach, which allows the understanding and interpretation of social reality from a critical and reflective perspective.</p>	 <p>Educational research is enriched when it engages with other disciplines and when it moves beyond the classroom to work with individuals and communities. Training researchers requires more humane, collaborative, and critical practices, capable of generating relevant and transformative knowledge.</p>

Trainer of trainers, educational research, human development.

Pensar cómo formamos a quienes investigan en educación y el desarrollo humano		
Objetivos	Metodología	Contribución
 <p>Objetivo: Reconocer como los tres ejes de análisis se articulan para reconstruir los vínculos de la investigación educativa.</p>	 <p>Tipo documental, se desarrolla bajo un enfoque cualitativo, el cual permite la comprensión e interpretación de la realidad social desde una perspectiva crítica y reflexiva.</p>	 <p>La investigación educativa se enriquece cuando participa con otras disciplinas y cuando sale del aula al trabajar con las personas y las comunidades. Formar investigadores exige prácticas más humanas, colaborativas y críticas, capaces de generar conocimiento relevante y transformador.</p>

Formador de formadores, investigación educativa, desarrollo humano

Area: Promotion of frontier research and basic science in all fields of knowledge

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## Introduction

In recent years, the conversation about how educational knowledge is constructed has undergone a profound shift. The questions that once guided the training of researchers are now insufficient because the world has changed rapidly, in a complex and sometimes disconcerting way. The way we learn, teach, and live together has been shaped by technological, social, cultural, and environmental transformations that cannot be ignored in the training of those who analyze and study educational phenomena. Continuing to train researchers with rigid frameworks or training models that no longer engage with reality condemns them to almost immediate obsolescence (Guerrero C.T., 2019).

Rethinking how we train researchers in education implies acknowledging that the ways of approaching knowledge are now broader, more hybrid, and more dynamic. Traditional methods still have value, but memorizing techniques, frameworks, or sequential steps is no longer enough to conduct research (Moreno Cardozo & Hernández Barbosa, 2025). What is needed today is a more flexible and critical perspective, capable of understanding the complexities of schools, communities, and individuals in training. The task is no longer simply to “apply an instrument,” but to understand living, diverse, and profoundly human processes (De la Cruz & Gallardo, 2024).

This analysis gives rise to three main ideas:

Education must incorporate emerging issues that are currently transforming social and educational life.

Research can no longer be confined to a single discipline. It must embrace interdisciplinarity and, where possible, move towards transdisciplinary, where theory merges with the realities of everyday life.

Future researchers require active, collaborative, and situated methodologies that connect them with authentic settings and help them develop critical thinking, creativity, and social awareness (Educación III, 2025).

From these three ideas emerge the three axes of analysis that organize the development of this article.

Through them, the aim is to reconstruct a more humane, sensitive proposal, one that is more connected to the challenges of the present, where educational research ceases to be seen as a distant theoretical process and becomes a tool for real transformation.

The objective of this study is to recognize how the three axes of analysis are articulated to reconstruct the links within educational research.

## Methodology

The methodology of this study is based on discourse analysis aimed at understanding both what is explicitly expressed and what remains implicit in texts about teacher training in educational research. A literature review was conducted using recognized academic databases, focusing on scientific articles, books, and institutional documents published in recent years, to identify approaches, recurring concepts, significant silences, and omissions in the academic discourse.

Texts were selected based on their thematic relevance, theoretical significance, and connection to research training processes in education. Subsequently, the documents were analysed interpretively, considering the context in which they were produced, the language used, and the positions they hold regarding the roles of teacher trainers and educational researchers. This study aims to identify tensions, points of convergence, and gaps in how teacher training is conceived, as well as the educational, sociocultural, and political-economic implications that arise from these discourses and their impact on human development

## Results

The following are the three key areas identified based on the tensions, points of convergence, and gaps observed.

### Key area 1. Emerging Issues Transforming the Training of Educational Researchers

21st-century education cannot be understood without considering a series of issues that, just two decades ago, seemed irrelevant to school life. Today, however, they shape public policy, teaching practices, and the concerns of researchers.

Some of these emerging issues—such as artificial intelligence, climate change, mental health, and intercultural education—are not academic fads, but rather profound dimensions that permeate school and social spaces. Integrating these themes is urgent in the training of researchers:

### 1. The use of artificial intelligence (AI)

In education is considered a tool that, since its arrival a few years ago, has permeated the educational field. It is not just digital platforms that improve and facilitate learning and teaching; it is a system capable of analysing large volumes of data, allowing for personalized learning pathways, and automating administrative tasks. However, beyond the technical aspects, what seems to be a concern is that AI invites us to redefine what it means to learn, teach, assess, and support students (Lozano Rodríguez and Ramírez Armenta, 2022).

Therefore, for those who train and are training as researchers, AI can introduce a developing field. Studying the impact of algorithms from an ethical perspective, the reproduction of biases, or the use of virtual assistants—but including AI in co-authorship with generative technologies or automated school monitoring—goes beyond mere technical skills. It demands a critical sensitivity to analyse what AI can contribute, and that's something it doesn't do; that's done by humans.

Future research will need professionals capable of interpreting data without losing sight of the human condition behind it. Understanding how machines interpret what we do in the classroom, how they redistribute workloads, or how they alter pedagogical relationships will be one of the core competencies of the contemporary educational researcher (Lozano Rodríguez and Ramírez Armenta, 2022).

### 2. Climate Change and Sustainability:

Educating for a Planet in Crisis, another unavoidable reality is the climate emergency. Schools, as spaces of socialization, are not immune to environmental effects or the practices that produce them. In many regions of the world, extreme heat affects school attendance, the quality of learning, and students' health; in others, natural phenomena disrupt school calendars and pose significant challenges to community resilience.

Faced with this, educational research cannot be limited to describing problems. It must contribute to redesigning strategies for care, adaptation, and sustainability. In several countries, action-research projects have been implemented in which students, teachers, and families work together to build local solutions: school gardens, rainwater harvesting systems, recycling campaigns, and clean energy projects.

When a future researcher participates in these kinds of experiences, their approach to research and their perspective on education change completely. They no longer observe the world from an academic distance, but rather from the awareness that knowledge must help sustain life.

### 3. Mental Health and Educational Neuroscience: Emotions at the Center

For a long time, educational research remained detached from mental health. However, today we understand that the emotions, emotional stability, and well-being of students and teachers have a direct impact on learning, coexistence, and school retention. Emotional overload, academic stress, online violence, and adverse socioeconomic conditions have increased the warning signs.

Therefore, the most current training programs include neuroeducation seminars, socio-emotional intervention strategies, and analyses of well-being practices in the classroom. Students preparing to conduct research develop projects that address topics ranging from school climate to the effects of trauma, integrating observation tools, interviews, and evidence-based intervention design.

This perspective helps move beyond a dehumanized research model and toward more sensitive approaches, where learning is not reduced to standardized measurements but recognizes the student as a whole person.

### 4. Interculturality and Dialogue Among Knowledges: An Unavoidable Challenge

Latin America and many countries around the world are experiencing a cultural awakening in which identities, languages, and traditional knowledge are seeking a legitimate place within formal education. Today's researchers must be able to interpret this diversity without oversimplifying it.

Incorporating intercultural education into research training implies learning to listen to the voices that have historically been marginalized: Indigenous peoples, rural communities, migrant groups, and displaced families. Knowledge production ceases to be a unilateral act of the researcher and becomes a shared process, where horizontal dialogue is as important as methodology.

The presence of these emerging themes transforms the very identity of the researcher, who is no longer seen as a technician of the method, but as a professional capable of understanding the complexity of the contemporary world.

## Theme 2. Interdisciplinarity and Transdisciplinary: Breaking Down Barriers to Better Understand Education

Education is a broad field of study, linked to social life, that cannot be understood from a single discipline. For years, attempts were made to study schools from strictly theoretical pedagogical approaches; however, current problems—violence, migration, the digital divide, academic underachievement, mental health, inequality, and dropout rates—require a much broader perspective.

Therefore, contemporary research is moving toward interdisciplinarity and, in some cases, transdisciplinary. This shift involves not only combining different areas of knowledge but also allowing them to transform one another, ultimately creating new ways of understanding educational phenomena.

### 1. Interdisciplinarity: When Multiple Areas of Knowledge Analyse the Same Problem

Interdisciplinarity occurs when different areas of knowledge are combined to study a problem. In the field of education, this is clearly seen when researchers in pedagogy work alongside psychologists, sociologists, computer scientists, anthropologists, or public policy specialists (Cândido & de Souza Silva, 2024).

The benefits of this collaboration are numerous:

- it allows for understanding the problem from different dimensions;
- it avoids simplistic conclusions;

- it promotes hybrid methodologies;
- it strengthens theoretical frameworks;

It generates more comprehensive proposals for intervention in schools.

A common example occurs in studies on school violence: while pedagogy analyses educational practices, psychology explores behavioural patterns, sociology examines social structure, and technology provides tools for mapping digital networks. The result is a much richer understanding than would be produced by a single discipline.

### 2. transdisciplinary: When Research Blends with Real Life

Transdisciplinary goes a step further. It not only combines disciplines but also incorporates the voices, knowledge, and experiences of the social actors themselves. In this approach, graduate students or researchers work together with communities, teachers, families, or students to create shared solutions.

A very valuable example is found in projects where research students design educational materials in collaboration with rural communities. There, the school, the family, and the community become co-authors of the project. Theory and practice intertwine to form living knowledge that responds to real needs (DGESuM, 2022).

This type of experience changes how researchers conceive of their work. Instead of working from behind a desk, they engage with real people and contexts. They understand that education is not studied solely through concepts, but also through human relationships.

### 3. Why are interdisciplinarity and transdisciplinary indispensable today?

Because current educational problems are too complex to be analysed in isolation. The digital divide, the climate crisis, the post-pandemic emotional impact, and educational exclusion all require multiple perspectives. A researcher prepared for the 21st century is one who is not afraid to step outside their theoretical comfort zone and explore other conceptual territories.

Furthermore, transdisciplinary offers something that no other methodology can: the ability to construct knowledge with social meaning, cultural relevance, and ethical commitment. Therefore, scientific research from an educational perspective requires collaboration and dialogue.

### AXIS 3. Active Methodologies in the Training of Researchers with a Collaborative Approach

To train researchers capable of understanding lived reality, simply learning theory is insufficient. Methodologies are required that involve collaboration among students through real-world, situated, and meaningful processes. Active methodologies with a collaborative approach help future researchers develop skills such as observation and critical analysis, ultimately leading to cognitive flexibility through attentive listening, which enables them to generate solutions (Settati, Guzmán Ibarra, & Marín Uribe, 2021).

#### 1. Learning by Transforming with Action Research

Action research is considered one of the most powerful approaches in training researchers with an educational focus, regardless of the field of knowledge. The inquiry process consists of intervention, where students can learn by investigating and simultaneously transforming their environment, participating in its solution.

Therefore, when students conduct diagnostic assessments where they design strategies and evaluate results alongside teachers and community members, they come to understand that research goes beyond producing a technical report; it allows them to engage with people and their everyday realities (Delgado Caro, 2025).

#### 2. Experience-Based Seminar-Workshops

Another approach that contributes to training as a scientific researcher is the seminar-workshop. In these workshops, students work with case studies, design instruments, compare theories, develop proposals, and reflect together, in addition to attending a lecture. This type of learning environment helps break with the passivity of the traditional model and fosters a more dynamic, horizontal, and stimulating practice.

#### 3. Information and Communication Technologies, Knowledge Networks, and Collaborative Work

Digital technologies have expanded research scenarios. Today, it is possible to build databases, analyse interaction networks, design virtual interventions, and coordinate collaborative projects with teams from different countries.

Furthermore, international academic networks have become spaces where students can present their work, receive feedback, and participate in the collective construction of knowledge.

#### 4. Error, Reflection, and Creativity: Pillars in Researcher Training

Active methodologies foster more honest and profound learning because they recognize the value of error. When students experiment, make mistakes, and try again, they develop critical thinking and intellectual autonomy.

This perspective revitalizes research training because it gives students back the opportunity to create, imagine, and propose without fear of making mistakes (Fattore & Welti, 2025).

### Conclusions

Thinking about how we train those who conduct scientific research through education implies examining the limitations of traditional teaching models, which fail to capture the complexity of the modern world. Emerging topics—including artificial intelligence, climate change, mental health, interculturality, and neuroscience—are reshaping the landscape of study and demanding an expansion not only of the curriculum but also of methodological perspectives.

For this reason, interdisciplinarity and transdisciplinary are breaking down the most established paths to understanding that the phenomena of human development integrate not only diverse knowledge but also community experiences. Without them, scientific research in the education of research trainers, regardless of the field of study, risks remaining isolated or generating knowledge that is largely insignificant.

Active methodologies with a collaborative approach offer researchers in training direct practical experience that strengthens their critical thinking skills, creativity, and, above all, their social commitment. Scientific research, approached from an educational perspective in the training of researchers in the 21st century, requires professionals capable of engaging with diverse realities and developing proposals that address real-world problems.

Therefore, the training of future researchers will always evolve toward a model that is flexible and sensitive, but above all, committed to life, where its core principles center on the development of curiosity, ethics, and creativity.

### Proposals

- Reinststate curricula that incorporate emerging topics.
- Include courses on AI, sustainability, mental health, and intercultural education, integrated with real-world field experiences.
- Develop interdisciplinary training programs.
- Promote seminars and projects that bring together educators, psychologists, sociologists, computer scientists, anthropologists, and public policy experts.
- Promote transdisciplinary experiences with communities.
- Design projects where students, teachers, and communities collaborate to solve local problems, integrating academic and community knowledge. Strengthen active learning methodologies.
- Expand the use of action research, case studies, practical workshops, and reflective simulations.
- Encourage early publication.

- Motivate students to participate in student journals, conferences, and academic networks from their first semesters.
- Promote the critical and ethical use of technology.
- Teach students to analyze algorithms, identify biases, interpret data, and use AI as a complementary tool, not as a substitute for critical thinking.
- Create emotional support programs.
- Integrate socio-emotional tutoring to help students cope with academic pressure and maintain a healthy balance.
- Promote collaborative research networks.
- Establish agreements with national and international universities to broaden horizons and strengthen the research culture.

### Declarations

#### Conflict of interest

The authors declare no interest conflict. They have no known competing financial interests or personal relationships that could have appeared to influence the article reported in this article.

#### Author contribution

*Ramos-Jaubert, Rocío Isabel:* Contributed to the project idea, searched and selected texts using academic search engines, defined inclusion and exclusion criteria, and organized the documentary corpus.

*Muñoz López, Temístocles:* Conducted exploratory and analytical readings of the texts, identifying initial categories, key concepts, and recurring themes related to teacher training.

*Espericueta Medina, Marta Nieves:* Focused on the analysis of the discourse itself, paying attention to both explicit statements and the silences, omissions, and implicit assumptions present in the documents.

## Article

Ramírez Chávez, Jorge: Handled the triangulation of findings, the comparison of interpretations, and the integrated writing of the results, ensuring conceptual coherence and interpretive validity of the analysis.

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Available.

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**Abbreviations**

AI Artificial Intelligence

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












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## Web application for learning Mexican sign language

### Aplicación web para el aprendizaje de la lengua de señas Mexicana

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#### Abstract




The development of technological applications has transformed the way people learn. In this context, a web application was created with the purpose of promoting the learning of Mexican Sign Language and helping to reduce the communication barriers faced by the deaf community. The application provides an accessible and engaging experience through playful, interactive resources and the use of artificial intelligence. For its development, the prototyping methodology was used, which is based on building functional versions of the software when the requirements are unclear or not fully defined (Pressman, 2010). The results include several modules: courses, a dictionary, interactive games, a sign detector powered by artificial intelligence, a voice translator, and a communication forum. Overall, the application aims to break communication barriers and promote inclusive education through the learning of Mexican Sign Language.

#### Resumen

El desarrollo de aplicaciones tecnológicas ha transformado la forma de aprender. En este sentido, se creó una aplicación web cuyo propósito es promover el aprendizaje de la Lengua de Señas Mexicana, contribuyendo a reducir las barreras de comunicación que enfrenta la comunidad sorda. La aplicación ofrece una experiencia accesible y atractiva mediante recursos lúdicos, interactivos y el uso de inteligencia artificial. Para su desarrollo se utilizó la metodología en prototipos, su filosofía se basa en la construcción de versiones funcionales del software cuando los requisitos no son claros o no están completamente definidos (Pressman, 2010). Entre sus resultados destacan diversos módulos: cursos, diccionario, juegos interactivos, detector de señas con inteligencia artificial, traductor de voz y un foro de comunicación. La aplicación busca romper las barreras de comunicación y fomentar la educación inclusiva a través del aprendizaje de la lengua de señas mexicana.

Web application for learning Mexican sign language		
Objective	Methodology	Contribution
-Overall, the application aims to break communication barriers and promote inclusive education through the learning of Mexican Sign Language.	Prototypes Phases -Communication -Quick Planning -Rapid Design Modeling -Prototype Construction -Development, Delivery, and Feedback	-Its purpose is to promote the learning of Mexican Sign Language, helping to reduce the communication barriers faced by the deaf community.
		

Web Application, Mexican Sign Language, Learning

Aplicación web para el aprendizaje de la lengua de señas mexicana		
Objetivo	Metodología	Contribución
-El propósito es promover el aprendizaje de la Lengua de Señas Mexicana, contribuyendo a reducir las barreras de comunicación que enfrenta la comunidad sorda.	Prototipos Fases -Comunicación -Plan rápido -Modelado Diseño rápido del Prototipo -Construcción del Prototipo -Desarrollo, entrega, retroalimentación	-La aplicación busca romper las barreras de comunicación y fomentar la educación inclusiva a través del aprendizaje de la lengua de señas mexicana.
		

Aplicación Web, Lengua de Señas Mexicana, Aprendizaje

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Peer review under the responsibility of the Scientific Committee MARVID<sup>®</sup> in the contribution to the scientific, technological and innovation Peer Review Process through the training of Human Resources for continuity in the Critical Analysis of International Research.



## Introducción

Nowadays, technological applications have become a fundamental pillar of education. Aspects such as knowledge building, autonomous and meaningful learning, interaction, accessibility, flexibility, notifications, among others, create environments conducive to the teaching-learning process, which are based on web applications. This diversity allows users to choose from a range of possibilities for learning in person or remotely. According to [Luján Mora \(2002\)](#), a web application can be defined as an application in which the user, through a browser, makes requests to an application via the internet and receives a response that is displayed in the browser itself.

This work presents a web application for learning Mexican Sign Language (LMS), whose main objective is to promote and encourage the learning of Mexican sign language and reduce the communication barriers faced by the deaf or hearing-impaired community through an accessible learning experience with different course levels, playful and interactive resources, and the use of artificial intelligence for sign language learning.

According to the National Council for the Development and Inclusion of Persons with [Disabilities \(2016\)](#), sign language is the language used by deaf people in Mexico and has its own syntax, grammar and lexicon. It consists of visual signs with their own linguistic structure, which deaf people in our country use to identify and express themselves.

On the other hand, [Orri de Castorino, R. \(2007\)](#), cited in [Peña, Rodríguez and Fresquet \(2022\)](#), discusses the importance of sign language in the education of deaf people. He recognises that these people constitute a linguistic minority community, that 'their voice', sign language, expresses that they have their own culture, which they also have a legitimate right to disseminate.

He recognises that sign language is a means of instruction in academic teaching and learning processes, a source of cultural expression of a universe that is constructed from visual experience.

Therefore, from this context, the importance of the application as a technological tool for learning Mexican sign language lies in breaking down communication barriers, promoting inclusion, respect for linguistic diversity, and facilitating access to LSM for anyone who wishes to learn it, whether they are hearing impaired or hearing.

This innovative tool seeks to overcome communication barriers and promote the inclusion of the deaf community, playing a crucial role in promoting inclusion and accessibility for the deaf community. The interactive application features a dictionary, a translator, course levels, and educational games such as memory, crossword puzzles, word formation, among others.

The application is based on the Mexican Sign Language methodology of the 'Bridge Strategy' and the 'Alvar' method. It is supported by interpreters from both the DIF Oaxaca and the Yucatan State Deaf Association (ASEY), which facilitates autonomous learning of LMS, thus building their own knowledge.

According to the [World Bank \(2023\)](#), there are more than one billion people with disabilities worldwide, representing approximately 15% of the global population, with the prevalence of disability being higher in developing countries.

In Mexico, according to data from the [Ministry of Health \(2021\)](#), around 2.3 million people have hearing disabilities, of whom more than 50 per cent are over 60 years of age; just over 34 per cent are between 30 and 59 years of age and around 2 per cent are children.

In Oaxaca, according to the [Oaxaca State Congress \(2023\)](#), there are 68,388 people with hearing disabilities and 116,805 people with some difficulty hearing even when using electronic devices. Until 2003, Mexican Sign Language was recognised as a national language, which set the tone for promoting and preserving this language. However, the problem lies in the fact that many hearing people or those without this disability are unfamiliar with sign language, which makes it difficult to communicate with people who are part of the deaf community. This lack of knowledge creates barriers that limit inclusion and communication with people with this disability.

Discrimination is another problem, as there are cases where people with language disabilities are stigmatised or treated unfairly.

The lack of opportunities, time, and resources makes it difficult for them to learn sign language in person.

Hence the importance of using the web application, as it facilitates the teaching and learning process of Mexican sign language, meaning that learning is presented in a simple and playful way anytime, anywhere.

This work covers the following sections: methodology, development, conclusions, statements, conflict of interest, authors' contributions, availability of data and materials, acknowledgements, abbreviations, and references.

## Methodology

Software development methodologies are a set of techniques and organisational methods that are applied to design computer software solutions. The aim of the different methodologies is to try to organise work teams so that they can develop the functions of a programme in the best possible way (Santander, 2024).

Sommerville (2005) defines software methodology or model as "A simplified representation of a software process, represented from a specific perspective. By their nature, models are simplified; therefore, a software process methodology or model is an abstraction of a real process.

The development of the web application for learning Mexican sign language was based on a prototype methodology whose main objective is direct participation with the client in the construction of the software, helping to understand when requirements are unclear and helping to identify and define software requirements (Pressman, 2010).

The Prototyping methodology is based on the construction of a software prototype that is built quickly so that users can test it and provide feedback. This allows for fixing what is wrong and including other requirements that may arise. It is an iterative model based on trial and error to understand the specifics of the product (Santander, 2024).

Bennett (2024) mentions that it is a software development model in which a prototype is built, tested, and reworked until an acceptable prototype is achieved. It also creates the basis for producing the final system or software. It works best in scenarios where the project requirements are not known in detail. It is an iterative, trial-and-error method carried out between the client and the developer. Salazar, Aguirre, and Osorio (2011) mention that the objective of the prototype methodology is to understand user requirements and work to improve their quality.

## Development

In the development of the web application, three prototypes were created through its different phases.

Following the phases of Pressman (2010), they are described below:

*Phase 1, Communication.* In this phase, an interview was conducted with Maestra Violeta Monserrat Alcántara Ramírez, Attorney for the Defence of Persons with Disabilities of the DIF (National System for Integral Family Development) Oaxaca, to better understand the needs related to Mexican Sign Language (LSM). The general and specific objectives of each prototype were defined, and the scope and limitations were established.

Likewise, an interview was conducted with interpreter Angélica Paulina Huerta Gómez, who explained the contextualisation of deaf culture in the DIF. An interview was also conducted in a virtual session via Meet with the sign language interpreter of the Yucatán State Deaf Association (ASEY), Dr Alvar Adrián May Can, on the problems faced by people with hearing disabilities in Yucatán and the challenges they have faced.

In phase 2, *Quick Plan*, the schedule of activities and the meeting plan were drawn up, and the functional and non-functional requirements of the *user, course, dictionary, games, sign detector, translator and forum* modules were identified, applying the user story technique, which (Cohn, 2016) 'a representation of a requirement written in one or two sentences using the user's common language.'

*Rapid design* in this phase focuses on representing those aspects of the software that will be visible to end users. Different types of UML diagrams (sequence, classes) were designed, the entity-relationship diagram and relational model were designed, the database was created using MySQL, and the graphical user interfaces were designed.

The architecture of the web application was based on a client-server model. According to Lujan Mora (2002), on the one hand, there is the client (the browser), who makes the requests, and on the other hand, there is the server (the web server), which is responsible for sending the response to the requests made by the client.

*Prototype construction.* In this phase, the different modules were coded using the JavaScript programming language and React Native, which is an open-source framework.

In the case of the Sign Detector module, artificial intelligence was used through a convolutional artificial neural network for image detection and recognition using the YOLO (You Only Look Once) v11 model designed for the recognition of letters (“A” to “Y”) of the dactylogical alphabet or Mexican manual alphabet, which is a set of 27 signs corresponding to a letter of the spoken Spanish alphabet. For the purposes of this article, the use of artificial intelligence is only mentioned briefly, as it will be the subject of another article in the future.

It is important to mention that the web application modules are based on the Mexican Sign Language methodology of the ‘Bridge Strategy’ is a teaching strategy that serves as a link or connection between the deaf community and the school or general learning system, facilitating the transition and linguistic and social development of deaf students.

The ‘Alvar’ method is an educational proposal designed for teaching Mexican Sign Language grammar. It is specially designed for students, teachers, and anyone who is hearing or deaf to learn LSM. The development of the application is supported by the advice of interpreters from DIF Oaxaca and the Yucatan State Deaf Association (ASEY).

Phase 5. *Deployment, delivery and feedback.* The application is evaluated by members of DIF Oaxaca and ASEY to validate that the design of the graphical user interfaces is simple, attractive and easy to use. They also validate that the elements of LSM are displayed in the interfaces, aspects such as: Querology, which is a discipline that studies the fundamental parameters of signs, defines how these manual representations are formed and used. Its main parameters include: *hand configuration*, which describes the shape and position of the hand when making a sign, including the use of individual fingers or combinations of fingers.

Movement, which details the actions of the hand, such as the direction, speed, and duration of the movement (May & Cabanzo, 2025), and Dactylology, which is the spelling of words through signs that directly represent a word. Through it, any word that one wishes to communicate can be transmitted to the deaf person. Spelling is an important part of the communication system of deaf people (May & Cabanzo, 2025).

User-centred tests were applied to determine the validation and functionality of the application in each prototype, as well as the training of the artificial neural network for sign recognition. It was contextualised at the Melchor Ocampo Primary School, where third, fourth, fifth and sixth grade students used the web application to learn Mexican sign language in order to test its functionality and enrich the application with their contributions and feedback.

During the development of the project, this process is repeated, i.e., the functional prototype is built and evaluated by the client until the requirements are met and they are satisfied with the software developed.

## Results

As a result of the development of the web application, the welcome screen and the modules that make up the application are shown, as shown in Figure 1.

**Box 1****Figure 1**

Web application welcome screen

The course module contains the different course levels, such as general, basic, intermediate, and advanced, see Figure 2.

**Box 2****Figure 2**

Course module of the web application

With the advice of sign language interpreters, they specify that learning Mexican sign language must begin with the General course, which covers the finger alphabet and numbers.

This interface shows elements to be taken into account. At the top of the screen is the name of the letter, on the left are instructions for making the sign, and on the right is an image of the sign on a white background.

This structure must be followed only for the content of the General course. It is important to note that all the images of the signs used in the application were created by the team members and validated by Mexican sign language interpreters (see Figure 3).

**Box 3****Figure 3**

Sign for the letter C in the alphabet

In the case of basic, intermediate, and advanced courses, there are learning sessions and assessments based on categories or semantic fields. This means that there is a group of words or, in this case, signs that are related by their meaning. For example, 'chair', 'table', "sofa" and "shelf" belong to the semantic field or category of "furniture". Based on the advice of interpreters, the interface designs must comply with the elements of Mexican sign language, such as querology and dactylogy.

This example shows: the sign, followed by an image that represents it, then the word in Spanish, and finally the word spelled in sign language (see Figure 4).

**Box 4****Figure 4**

Interface of the sign for the pronoun "I"

Figure 5 shows the sign language dictionary module, which allows users to search by word or category. Users must type the word they want to search for in the search box and then select the magnifying glass button.

The sign, the Spanish word, and the spelling in Mexican Sign Language will appear at the bottom.

**Box 5****Figure 5**

Dictionary Module

Various interactive games were implemented, such as memory, crossword puzzles, word formation, sign writing, word ordering, matching pairs, and word searches, to practise and reinforce Mexican sign language. Each game has its own assessment to track progress levels. Figure 6 shows the game menu available in the application.

**Box 6****Figure 6**

Word Sorting Game

Implementation of the Sign Detector module with artificial intelligence. This screen displays an image captured by the user from the camera in real time. It contains an Activate/Deactivate button to start the sign detector and displays instructions so that the user can make the sign.

**Box 7****Figure 7**

Signal detector

The voice translator module allows the user to select the microphone button to say a word or sentence, and the translation in Mexican sign language is displayed at the bottom of the screen, see Figure 8.

**Box 8****Figure 3**

Voice translator module

Finally, the communication forum module, which allows users to create posts by adding a title and content and interacting with other users, with the aim of exchanging ideas, learning more about a particular topic, or commenting on topics of common interest in Mexican sign language, is shown in Figure 9.

**Box 9****Figure 9**

Rafael-Pérez, Eva, Pérez-Sánchez, Jorge, Morales-Hernández, Maricela, and Altamirano-Cabrera, Marisol. [2025]. Web application for learning Mexican sign language. Journal of Technical Education. 9[21]1-8: e7921108.

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## Conclusions

The completion of this project marks a crucial step forward in the preservation of Mexican Sign Language.

The development of this application for learning Mexican Sign Language represents a significant step towards inclusion and accessibility in education. Through a combination of artificial intelligence, interactive games and structured courses, the application offers an innovative tool for learning LSM, both for deaf and hearing people.

The application has not only succeeded in offering an interactive and accessible educational resource for learning Mexican Sign Language, but has also become a driver of cultural revitalisation, as its impact transcends the technological and educational spheres by strengthening the value of sign language within the deaf community.

In terms of future work, there are plans to expand the sign detection module, add a video module, and develop a virtual robotic arm with machine learning for teaching sign language to children with motor disabilities.

Finally, a standard LSM module will be added to include other signs from different countries.

## Declarations

### Conflict of interest

The authors declare no conflict of interest. They have no known competing financial interests or personal relationships that could have appeared to influence the article reported in this article.

### Contributions of the authors

*Rafael-Pérez, Eva*: Contributed with the project idea, research development, application design, review and validation of tests, and project operation.

*Pérez-Sánchez, Jorge*: Contributed with project development, design and application of module tests, review and editing of the work.

*Morales Hernández, Maricela*: Contributed to the review, editing, and preparation of the results.

*Marisol Altamirano Cabrea*: Contributed to the review and validation of the graphical user interfaces and the tests performed.

### Data availability and references

For more information, please contact the following email address: [eva.rafael@itoaxaca.edu.mx](mailto:eva.rafael@itoaxaca.edu.mx)

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We would also like to acknowledge and thank interpreter Alvar Adrián May Can from the Yucatán State Deaf Association (ASEY) for all his advice, support and reviews of the project in various Meet sessions on the grammar and application of the ‘Alvar’ method of Mexican Sign Language.

We would also like to acknowledge and thank the headmistress of the Melchor Ocampo Primary School, Professor Celiflora Rafael Pérez, for allowing third, fourth, fifth and sixth grade students to use the Mexican Sign Language learning application to test its functionality and enrich the application with their contributions.

Likewise, we would like to thank the National Technological Institute of Mexico, which, through its Oaxaca Campus, has provided the space and resources for the development of this project.

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Article

**Abbreviations**

MySQL My Structured Query Language  
 UML Unified Modeling Language  
 YOLO You Only Look Once

*Consejo Nacional para el Desarrollo y Inclusión de las Personas con Discapacidad.* (2016). Lengua de Señas Mexicana (LSM). gob.mx.

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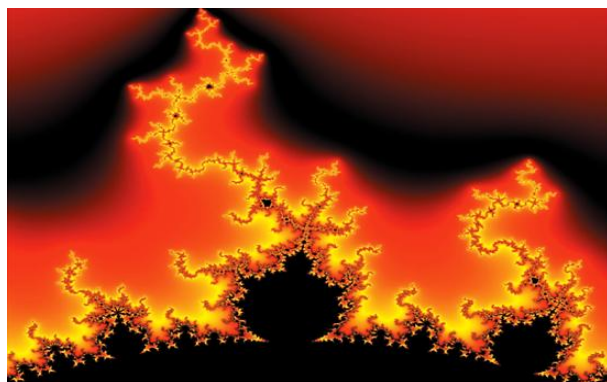
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