DIGITALEDUCATIONREVIEW

Use of the deep learning and decision tree techniques to analyze the incorporation of technology in the educational field

Ricardo-Adán Salas-Rueda [1*], Ricardo Castañeda-Martínez [2], Jesús Ramírez-Ortega [3], Selene-Marisol Martínez-Ramírez [4]

[1] Escuela Nacional de Ciencias de la Tierra, Universidad Nacional Autónoma de México, México, ricardo.salas@encit.unam.mx, http://orcid.org/0000-0002-4188-4610
[2] Instituto de Ciencias Aplicadas y Tecnología, Universidad Nacional Autónoma de México, México, ricardo.castaneda@icat.unam.mx, https://orcid.org/0000-0002-2225-7136
[3] Instituto de Ciencias Aplicadas y Tecnología, Universidad Nacional Autónoma de México, México, jesus.ramirez@icat.unam.mx, https://orcid.org/0000-0002-4538-9203
[4] Instituto de Ciencias Aplicadas y Tecnología, Universidad Nacional Autónoma de México, México, selene.martinez@icat.unam.mx, https://orcid.org/0000-0002-4446-7396

ABSTRACT

The aim of this mixed research is to analyze the perception of the students about the use of Zoom and the Learning Management Systems such as Moodle and Google Classroom in the educational field during the COVID-19 pandemic considered data science. In particular, Zoom facilitates the communication, presentation of contents and resolution of doubts. On the other hand, Moodle and Google Classroom allow the delivery of tasks, consultation of information and realization of discussion forums from anywhere. The participants are 128 students of Psychology (n = 70, 54.69%), Social Work (n = 33, 25.78%) and Geophysics (n = 25, 19.53%) who took the Clinical Method, Urban Problems and Electromagnetic Prospecting courses at the National Autonomous University of Mexico during the 2020 school year. The results of the deep learning technique indicate that the use of Zoom and Learning Management Systems (Moodle and Google Classroom) during the COVID-19 pandemic positively influences the assimilation of knowledge and participation of the students. The decision tree technique identifies 4 predictive models about the use of these technological tools. Finally, Zoom, Moodle and Google Classroom allow transforming the teaching-learning process and updating the school activities during the COVID-19 pandemic.

KEYWORDS: Technology; ICT; LMS; COVID-19; Data science

1 INTRODUCTION

Technological advances have caused educators to more frequently use Zoom and Learning Management Systems to organize and carry out the school activities in virtual, mixed and in-person modalities. In fact, these technological and communication tools have transformed the functions of the educators and students during the teaching-learning process.

The COVID-19 pandemic provoked that educational institutions seek new ways to carry out the school activities in the distance modality (Dahri et al., 2024; Jandric et al., 2020; Qin et al., 2022; Rapanta et al., 2020). In fact, Information and Communication Technologies (ICTs) play a fundamental role during the updating of the courses and creation of new educational spaces (Adouani & Khenissi, 2024; Altakhayneh, 2022; Cirigliano et al., 2020; Gillingham et al., 2020). For example, video conferencing systems are transforming the communication and interaction between the students and teachers (Ballejos et al., 2018; Knapp, 2018). In particular, Zoom facilitates the exchange of ideas in real time during the teaching-learning process (Amjadi et al., 2024; Gende, 2020).

Likewise, Learning Management Systems allow the organization and realization of new school activities outside and inside the classroom (Badia et al., 2019; Ibañez et al., 2020; Qin et al., 2022; Wut et al., 2024). For example, the use of Moodle and Google Classroom in the educational field facilitate the dissemination of homework and school contents, allow the communication at any time and promote the active role (Aunimo et al., 2024; Badia et al., 2019; Gamage et al., 2019).

Universities are transforming the planning of the school activities with the support of technological8 advances to build creative virtual learning spaces and facilitate the distance education (Castillo-Cuesta et al., 2022; Eiland, 2018; Howard & Benedicks, 2020; Wut et al., 2024). Therefore, the incorporation of digital tools in the educational field has a fundamental role to realize the teaching process during the COVID-19 pandemic (Maggio, 2020; Ramírez-Montoya, 2020; Wu et al., 2024). In particular, Zoom facilitates the communication, presentation of contents and resolution of doubts. On the other hand, Learning Management Systems such as Moodle and Google Classroom allow the delivery of tasks, consultation of information and realization of discussion forums from anywhere.

Machine Learning algorithms together with Data Science allow analyzing and evaluating the technological and educational phenomena from another perspective. Therefore, the aim of this mixed research is to analyze the perception of the students about the use of Zoom and Learning Management Systems (Moodle and Google Classroom) in the Clinical Method, Urban Problems and Electromagnetic Prospecting courses during the COVID-19 pandemic through data science. The research questions are:

- What is the perception of the students about the use of Zoom and Learning Management Systems (Moodle and Google Classroom) for the assimilation of knowledge and participation during the Clinical Method, Urban Problems and Electromagnetic Prospecting courses considering the deep learning technique?
- What are the predictive models about the use of these Learning Management Systems and Zoom in the educational field considering the decision tree technique?
- What are the perceptions of the students about the use of Zoom, Moodle and Google Classroom during the COVID-19 pandemic?

2 LITERATURE REVIEW

Learning Management Systems and video conferencing systems are changing the way of carrying out the teaching-learning process during the COVID-19 pandemic because these technological tools allow the creation of virtual spaces and organization of new activities focused on students in the distance modality (Aunimo et al., 2024; Gende, 2020; Ibañez et al., 2020). In fact, the incorporation of ICTs in the educational field facilitates the communication, participation and interaction at any time (Altakhayneh, 2022; Howard & Benedicks, 2020; Liu et al., 2018).

2.1 Use of video conferencing systems in the educational field

Today, the use of video conferencing systems such as Zoom, Google Meet and Teams allowed the realization of the learning process and facilitated the communication between the participants of the educational process from anywhere (Amjadi et al., 2024; Ballejos et al., 2018; Gende, 2020). In the Physics course, the students used Zoom to observe the teacher's presentation and discuss the school contents (Gende, 2020). In the same way, this video conferencing system facilitated the understanding of the topics in the medicine course (Ballejos et al., 2018).

The benefits of the incorporation of video conferencing systems in the educational field are the flexibility of space during the learning process, performance of the school activities in the distance modality, communication and exchange of ideas (Ballejos et al., 2018; Gende, 2020; Westervelt et al., 2018). In the Physical Therapy course, the use of video conferencing systems allowed the development of critical thinking (Westervelt et al., 2018). For example, the teacher's presentations in Zoom facilitated the assimilation of knowledge about spinal problems and improved the participation of the students (Westervelt et al., 2018).

During the distance education, video conferencing systems are essential because these technological tools facilitate the teaching-learning process and develop the students' skills (Knapp, 2018; Maggio, 2020; Ramírez-Montoya, 2020). In fact, educational institutions such as universities promote the use of Zoom, Google Meet and Teams in the school activities to make the presentations of the topics and participate in the discussion forums from anywhere (Knapp, 2018).

Finally, video conferencing systems have become a key element for the teaching-learning process during the COVID-19 pandemic because this technological tool allows solving the doubts of the students (Maggio, 2020; Ramírez-Montoya, 2020). In addition, the use of Zoom allowed establishing an efficient communication in the courses of Physics (Gende, 2020), Physical Therapy (Westervelt et al., 2018) and Medicine (Ballejos et al., 2018).

2.2 Use of Learning Management Systems in the educational field

During the 21st century, Learning Management Systems such as Moodle, Blackboard, Canvas and Google classroom are used by teachers to organize new school activities for the face-to-face sessions and distance courses (Badia et al., 2019; Gende, 2020; Heyde & Siebrits, 2019). For example, the students of the Physics course used Google classroom to consult the materials, assignments, information and videos before, during and after the classes (Gende, 2020).

Similarly, the incorporation of the Sakai platform in the educational field facilitated the assimilation of knowledge about physics, participation in the discussion forums and realization of the online exams (Heyde & Siebrits, 2019). The benefits about the use of this educational web platform are the increase of the academic performance, active role and autonomy of the students during the learning process about physics (Heyde & Siebrits, 2019).

The incorporation of Learning Management Systems in the educational field promotes the interest and enthusiasm of the students during the teaching-learning process through the discussion forums (Badia et al., 2019; Heyde & Siebrits, 2019). In particular, the use of Moodle in the secondary schools facilitated the assimilation of knowledge through the realization of online exams and consultation of information from anywhere (Badia et al., 2019).

In the Science courses, the students used Moodle to facilitate the dissemination of the school contents (Gamage et al., 2019). Likewise, this technological tool improved the academic performance and participation of the students through the online exams and discussion forums (Gamage et al., 2019). Finally, Learning Management Systems such as Moodle, Blackboard and Google classroom facilitate the

teaching-learning process and allow the realization of the school activities at any time (Badia et al., 2019; Heyde & Siebrits, 2019; Ibañez et al., 2020).

2.3 Machine Learning algorithms in the educational field

Machine Learning is a branch of Artificial Intelligence that is revolutionizing all fields of knowledge (Ayanwale et al., 2024; Chang et al., 2024; Iyamuremye et al., 2024). According to Li et al. (2024), Machine Learning algorithms are used in the universities to predict the educational phenomena and adapt the school content.

In the educational context, Machine Learning algorithms are causing significant changes in the learning, teaching and academic performance (Ayanwale et al., 2024; Barelli et al., 2024; Zhai et al., 2023). In fact, the incorporation of technology in the school activities is closely related to these Artificial Intelligence algorithms to analyze its impact (Ayanwale et al., 2024; Chang et al., 2024; Salas-Rueda et al., 2024).

The Deep Learning algorithm is used to improve the quality of teaching and results of the learning process (Shiao et al., 2023). For example, Shiao et al. (2023) used the Deep Learning algorithm to predict the number of students who drop out of the schools considering the health-related factors, mismatched interest, maladaptation, failed examination, study abroad and poor academic performance.

Li et al. (2024) used various Machine Learning algorithms such as Decision Tree, Support Vector Machine (SVM), Random Forest, Neural Network, Naive Bayes, Logistic Regression and Gradient Boosting Machine to predict the school activities on the web platform carried out by the Medical students.

In the Chemistry courses, Machine Learning algorithms are used to create the personalized learning experiences, facilitate the access to materials, assist the teachers, build the adaptive platforms, and forecast the educational events (Iyamuremye et al., 2024).

Likewise, Chang et al. (2024) built a system based on Machine Learning algorithms called Ladder to analyze the learning attitudes, self-regulated learning, AI anxiety, individual impact, computational thinking abilities and cognitive styles during the Computer Science course.

Finally, Salas-Rueda et al. (2024) used the Deep Learning algorithm to evaluate and predict the motivation and creativity considering the use of technology under the Flipped Classroom modality in the Geography course. In fact, this Machine Learning algorithm established six predictive models on the activities carried out before, during and after the classes (Salas-Rueda et al., 2024).

3 METHOD

The particular aims are (1) analyze the perception of the students about the use of Zoom and Learning Management Systems (Moodle and Google Classroom) for the assimilation of knowledge and participation during the Clinical Method, Urban Problems and Electromagnetic Prospecting courses considering the deep learning technique (2) identify the predictive models about the use of these Learning Management Systems and Zoom during the COVID-19 pandemic considering the decision tree technique and (3) analyze the students' perceptions about the use of Moodle, Google Classroom and Zoom in the educational field.

To analyze the variables of this study, a questionnaire was created, which is validated using the following criteria: Load Factor, Cronbach's Alpha, Average Variance Extracted and Composite Reliability (See Table 2).

3.1 Participants

The participants are 128 students (43 men and 85 women) of Psychology, Social Work and Geophysics who took the Clinical Method, Urban Problems and Electromagnetic Prospecting courses in the distance modality at the National Autonomous University of Mexico during the 2020 school year.

The sample was non-probabilistic and the courses were selected because the teachers participated in the PAPIME project called Classroom of the Future. This mixed study was based on the descriptive, causal and correlational scopes.

The students of Psychology (n = 70, 54.69%) took the Clinical Method course and have an average age of 19.35 years. The students of Social Work (n = 33, 25.78%) took the Urban Problems course and have an average age of 21.18 years. Finally, the students of Geophysics (n = 25, 19.53%) took the Electromagnetic Prospecting course and have an average age of 22.68 years.

3.2 Procedure

The National Autonomous University of Mexico offers the “Innovation in University Teaching 2020” Diploma to improve the teaching-learning process through the use of the pedagogical and technological model called “Classroom of the Future model” (See Figure 1). In particular, the teachers of Clinical Method, Urban Problems and Electromagnetic Prospecting courses took this diploma to improve the organization of the school activities during the COVID-19 pandemic.

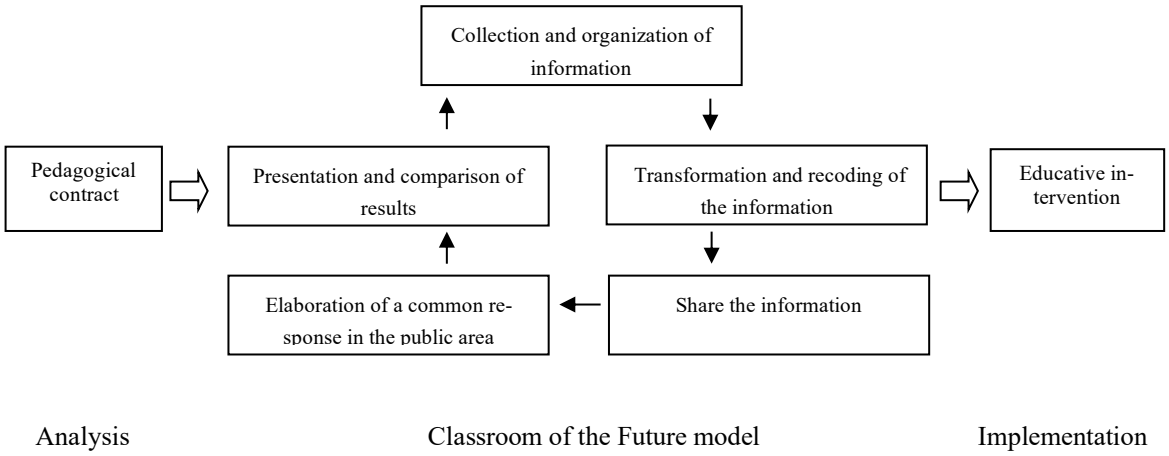


Figure 1. "Innovation in University Teaching 2020" Diploma
Source: created by the authors

In the Clinical Method and Urban Problems courses, the teachers incorporated Zoom and Moodle in the school activities. On the other hand, the teacher of Electromagnetic Prospecting course used Zoom and Google Classroom. Figure 2 shows the model used.

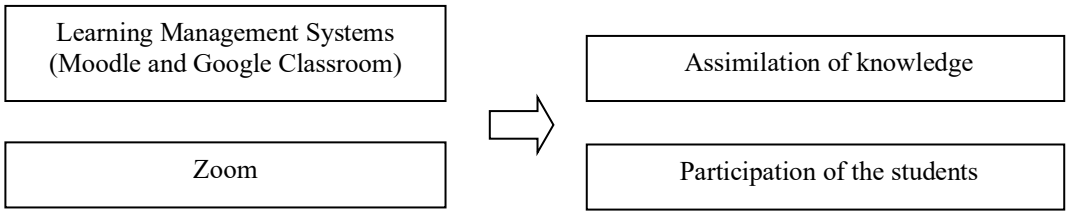


Figure 2. Model about the use of Learning Management Systems and Zoom
Source: created by the authors

The incorporation of ICTs in the educational context allows the organization and construction of new spaces for learning and teaching (Cirigliano et al., 2020; Eiland, 2018; Riopel et al., 2019). Therefore, the hypotheses about the use of technological tools and assimilation of knowledge are:

- Hypothesis 1 (H1): The use of the Learning Management Systems (Moodle and Google Classroom) during the COVID-19 pandemic positively influences the assimilation of knowledge
- Hypothesis 2 (H2): The use of Zoom during the COVID-19 pandemic positively influences the assimilation of knowledge

During the planning and implementation of the school activities, teachers use ICTs in order to promote the active role of the students (Altakhayneh, 2022; Hetherington et al., 2018; Ruschenpohler & Markic, 2019). Therefore, the hypotheses about the use of technological tools and participation are:

- Hypothesis 3 (H3): The use of the Learning Management Systems (Moodle and Google Classroom) during the COVID-19 pandemic positively influences the participation of the students
- Hypothesis 4 (H4): The use of Zoom during the COVID-19 pandemic positively influences the participation of the students

The predictive models about the use of the Learning Management Systems and Zoom in the educational field during the COVID-19 pandemic are:

- Predictive Model 1 (PM1) about Learning Management Systems and assimilation of knowledge
- Predictive Model 2 (PM2) about Zoom and assimilation of knowledge
- Predictive Model 3 (PM3) about Learning Management Systems and participation
- Predictive Model 4 (PM4) about Zoom and participation

3.3 Data collection

Table 1 shows the digital questionnaire about the use of the Learning Management Systems and Zoom in the educational field. In addition, it was applied in the month of November 2020. The variables are Profile, Use of technology and Students' perception.

No.	Variable	Dimension	Question	Answer	n	%
1	Profile of the students	Sex	1. What is your sex?			
				Man	43	33.59%
				Woman	85	66.41%
		Age	2. What is your age?			
				18 years	5	3.91%
				19 years	50	39.06%
				20 years	19	14.84%
				21 years	17	13.28%
				22 years	16	12.50%
				23 years	12	9.38%
				24 years	5	3.91%
				> 24 years	4	3.13%
		Career	3. What career are you studying?			
				Psychology	70	54.69%
				Social Work	33	25.78%
				Geophysics	25	19.53%
2	Use of technology	Learning Management Systems	4. The use of the Learning Management Systems (Moodle and Google Classroom) facilitates the learning process during the COVID-19 pandemic			
				Very much (1)	34	26.56%
				Much (2)	52	40.63%
				Little (3)	38	29.69%
				Very little (4)	4	3.13%
		Zoom	5. The use of Zoom facilitates the learning process during the COVID-19 pandemic			
				Very much (1)	41	32.03%
				Much (2)	66	51.56%
				Little (3)	19	14.84%
				Very little (4)	2	1.56%
		Assimilation of knowledge	6. The use of ICTs improves the assimilation of knowledge			
				Very much (1)	22	17.19%
				Much (2)	57	44.53%
				Little (3)	47	36.72%
				Very little (4)	2	1.56%
		Participation of the students	7. The use of ICTs improves the participation of the students during the educational process			
				Very much (1)	15	11.72%
				Much (2)	42	32.81%
				Little (3)	56	43.75%
				Very little (4)	15	11.72%
3	Students' perception	Learning Management Systems	8. What is your opinion about the use of the Learning Management Systems (Moodle or Google Classroom)?	Open	-	-
		Zoom	9. What is your opinion about the use of Zoom?	Open	-	-

Table 1. Questionnaire about the Learning Management Systems and Zoom
Source: created by the authors

Table 2 shows that the values of the Load Factor (> 0.530), Cronbach's Alpha (> 0.660) and Composite Reliability (> 0.800) allow to validate the questionnaire.

Variable	Dimension	Load Factor	Cronbach's Alpha	Average Variance Extracted	Composite Reliability
Use of technology	Learning Management Systems	0.722	0.669	0.515	0.806
	Zoom	0.793			

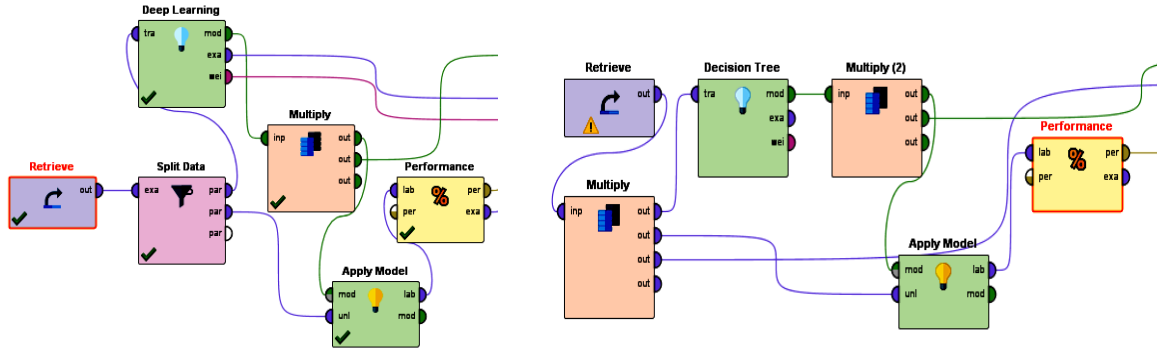
	Assimilation of knowledge	0.794			
	Participation of the students	0.531			

Table 2. Validation of the questionnaire
Source: created by the authors

3.4 Data analysis

This mixed research used the RapidMiner tool to calculate the linear regressions (machine learning) and build the predictive models about the use of Zoom and the Learning Management Systems (See Figure 3). In the deep learning technique, the training section uses 50% (n = 64), 60% (n = 77) and 70% (n = 90) of the sample to calculate the linear regressions and evaluate the research hypotheses. Likewise, the evaluation section uses 50% (n = 64), 40% (n = 51) and 30% (n = 38) of the sample to calculate the squared error and identify the accuracy of these linear regressions. The independent variables are the Learning Management Systems and Zoom. On the other hand, the dependent variables are Assimilation of knowledge and Participation of the students.

On the other hand, the information about profile of the students, Learning Management Systems (Moodle and Google Classroom) and Zoom allows building the predictive models by means of the decision tree technique. The objective variables are Assimilation of knowledge and Participation of the students. Finally, the Word Cloud application allows analyzing the students' perception about the use of ICTs in the educational field by identifying the most frequently used words.



(a) Deep learning (b) Decision tree technique

Figure 3. Use of the RapidMiner tool
Source: created by the authors

4 RESULTS

The use of the Learning Management Systems (Moodle and Google Classroom) facilitates very much (n = 34, 26.56%), much (n = 52, 40.63%), little (n = 38, 29.69%) and very little (n = 4, 3.13%) the learning process during the COVID-19 pandemic (See Table 1). In addition, the use of Zoom facilitates very much (n = 41, 32.03%), much (n = 66, 51.56%), little (n = 19, 14.84%) and very little (n = 2, 1.56%) the learning process during the COVID-19 pandemic. The results of the deep learning technique indicate that the use of Zoom and the Learning Management Systems (Moodle and Google Classroom) during the COVID-19 pandemic positively influences the assimilation of knowledge and participation of the students (See Table 3).

Hypothesis	Training	Hidden layers	Activation	Epochs	Linear regression	Conclusion	p-value
H1: Learning Management Systems → assimilation of knowledge	50%	50, 50	Tanh	10	y = 0.056x + 2.199	Accepted: 0.056	0.000
	60%				y = 0.041x + 2.254	Accepted: 0.041	0.000
	70%				y = 0.089x + 2.138	Accepted: 0.089	0.000
H2: Zoom → assimilation of knowledge	50%	50, 50	Tanh	10	y = 0.521x + 1.277	Accepted: 0.521	0.000
	60%				y = 0.392x + 1.556	Accepted: 0.392	0.000
	70%				y = 0.411x + 1.483	Accepted: 0.411	0.000
H3: Learning Management Systems	50%	50, 50	Tanh	10	y = 0.070x + 2.572	Accepted: 0.070	0.000
	60%				y = 0.138x + 2.403	Accepted: 0.138	0.000

→ participation of the students	70%				y = 0.156x + 2.229	Accepted: 0.156	0.000
H4: Zoom → participation of the students	50%	50, 50	Tanh	10	y = 0.246x + 2.153	Accepted: 0.246	0.000
	60%				y = 0.164x + 2.450	Accepted: 0.164	0.000
	70%				y = 0.112x + 2.342	Accepted: 0.112	0.000

Table 3. Results of the deep learning technique
Source: created by the authors

Table 4 shows the Pearson's correlations about the assimilation of knowledge, participation of the students, Learning Management Systems and Zoom.

	Learning Management Systems	Zoom	Assimilation of knowledge	Participation of the students
Learning Management Systems	1	-	-	-
Zoom	0.486	1	-	-
Assimilation of knowledge	0.336	0.517	1	-
Participation of the students	0.217	0.155	0.360	1

Table 4. Pearson's correlations
Source: created by the authors

4.1 Assimilation of knowledge

The use of ICTs improves very much (n = 22, 17.19%), much (n = 57, 44.53%), little (n = 47, 36.72%) and very little (n = 2, 1.56%) the assimilation of knowledge (See Table 1). The results of the deep learning technique with 50% (0.056), 60% (0.041) and 70% (0.089) of training indicate that H1 is accepted (See Table 3). Consequently, the use of the Learning Management Systems (Moodle and Google Classroom) during the COVID-19 pandemic positively influences the assimilation of knowledge.

Figure 4 shows 10 conditions of the PM1 to predict the assimilation of knowledge considering Learning Management Systems, career and sex. Also, the sex determined 8 conditions and career established 8 conditions of this predictive model. For example, if the student thinks that the use of the Learning Management Systems facilitates very much the learning process during the COVID-19 pandemic, has the career of Social Work and is a man then the use of ICTs improves very much the assimilation of knowledge.

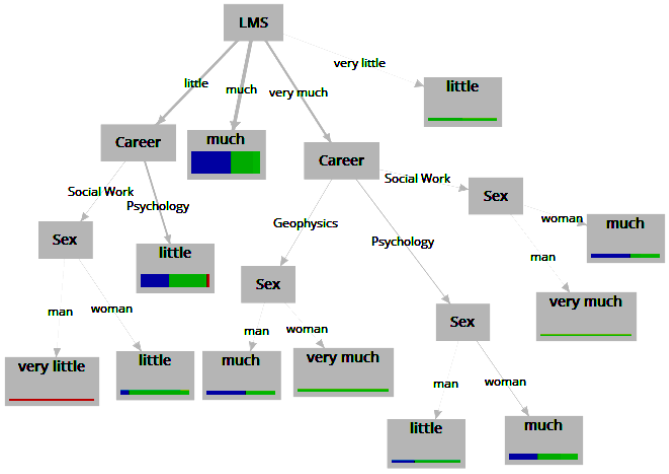


Figure 4. Conditions of the PM1.
Source: created by the authors

The results of the deep learning technique with 50% (0.521), 60% (0.392) and 70% (0.411) of training indicate that H2 is accepted (See Table 3). Therefore, the use of Zoom during the COVID-19 pandemic positively influences the assimilation of knowledge.

Figure 5 shows 10 conditions of the PM2 to predict the assimilation of knowledge considering Zoom, career and sex. Also, the sex determined 4 conditions and career established 8 conditions of this predictive model. For example, if the student thinks that the use of Zoom facilitates very much the learning process during the COVID-19 pandemic, has the career of Geophysics and is a woman then the use of ICTs improves very much the assimilation of knowledge.

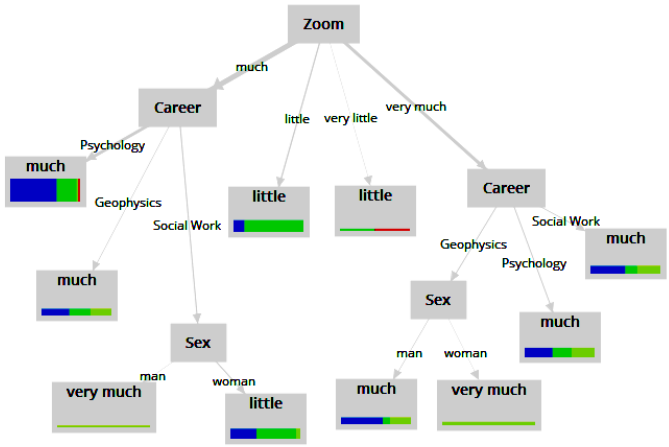


Figure 5. Conditions of the PM2.
Source: created by the authors

4.2 Participation of the students

The use of ICTs improves very much (n = 15, 11.72%), much (n = 42, 32.81%), little (n = 56, 43.75%) and very little (n = 15, 11.72%) the participation of the students during the educational process (See Table 1). The results of the deep learning technique with 50% (0.070), 60% (0.138) and 70% (0.156) of training indicate that H3 is accepted (See Table 3). Therefore, the use of the Learning Management Systems (Moodle and Google Classroom) during the COVID-19 pandemic positively influences the participation of the students.

Figure 6 shows 8 conditions of the PM3 to predict the participation considering Learning Management Systems, career and sex. Also, the sex determined 4 conditions and career established 8 conditions of this predictive model. For example, if the student thinks that the use of the Learning Management Systems facilitates very much the learning process during the COVID-19 pandemic and has the career of Psychology then the use of ICTs improves much the participation during the educational process.

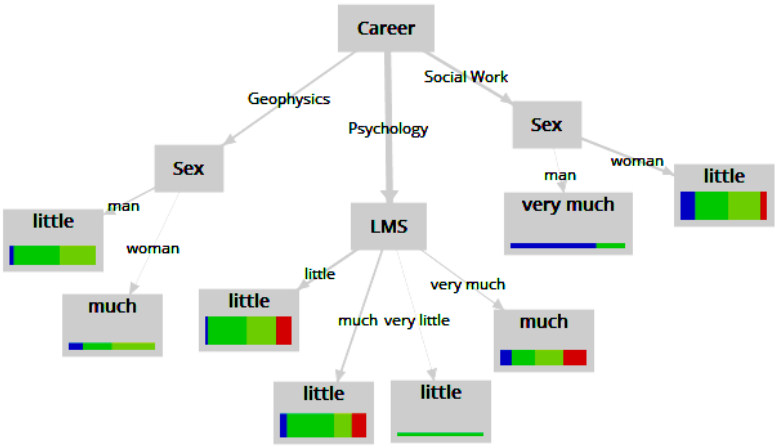


Figure 6. Conditions of the PM3.
Source: created by the authors

The results of the deep learning technique with 50% (0.246), 60% (0.164) and 70% (0.112) of training indicate that H4 is accepted (See Table 3). Therefore, the use of Zoom during the COVID-19 pandemic positively influences the participation of the students.

Figure 7 shows 8 conditions of the PM4 to predict the participation considering Zoom, career and sex. Also, the sex determined 2 conditions and career established 8 conditions of this predictive model. For example, if the student thinks that the use of Zoom facilitates much the learning process during the COVID-19 pandemic and has the career of Geophysics then the use of ICTs improves much the participation during the educational process.

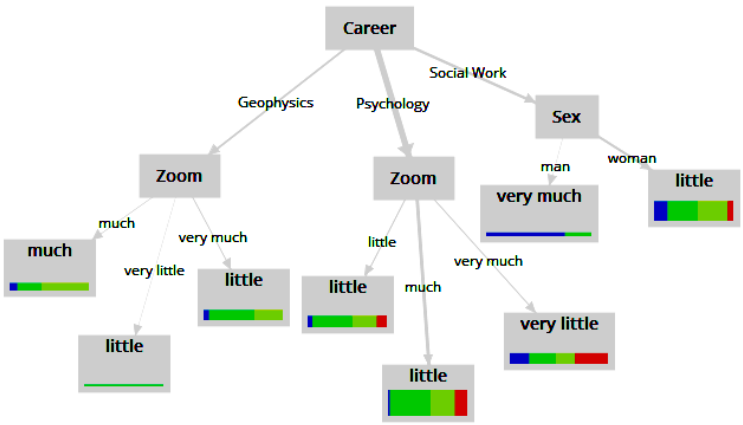


Figure 7. Conditions of the PM4.
Source: created by the authors

4.3 Students' perception

Video conferencing systems played a fundamental role during the organization of distance courses. According to the students of Psychology, Social Work and Geophysics, Zoom facilitated the interaction during the educational process.

- “It allows me to interact directly with the teacher” (Student 6, 23 years old, man).
- “It allows the interaction between the teacher and students to exchange the ideas” (Student 33, 22 years old, man).

During the COVID-19 pandemic, the teachers of the courses of Clinical Method, Urban Problems and Electromagnetic Prospecting transformed the learning process by incorporating ICTs in the school activities. In particular, the students used Zoom to ask questions during the live sessions.

- “If I have doubts then I can ask them during the live sessions” (Student 40, 23 years old, man).
- “We have a good feedback and discuss the doubts” (Student 61, 22 years old, man).

Educational institutions use video conferencing systems to facilitate the teaching-learning process in the distance modality. In particular, the use of Zoom improved the communication between the students and teachers of the National Autonomous University of Mexico.

- “Zoom facilitates the communication. There is an interaction” (Student 16, 24 years old, woman).
- “It allows the interaction in real time” (Student 50, 24 years old, man).

Figure 4 shows that the most frequent words about the use of Zoom in the educational field are: classes (n = 18), doubts (n = 17), teacher (n = 17), time (n = 10), interaction (n = 10), topics (n = 9), zoom (n = 6) and communication (n = 5).

Figure 4. Word cloud about Zoom.
Source: created by the authors

Learning Management Systems such as Moodle and Google Classroom facilitated the organization of the school activities in the distance modality. In fact, the students of Psychology, Social Work and Geophysics consulted the contents, resources and information of the courses at any time.

- “I have the material when I need it” (Student 43, 23 years old, man).
- “The sending of materials and messages in the platform facilitate the learning” (Student 61, 23 years old, woman).

The use of ICTs in the educational context facilitated the teaching-learning process at the National Autonomous University of Mexico. In particular, Moodle and Google Classroom allowed the delivery of assignments and realization of online exams.

- “I can carry out the questionnaires and tasks with feedback” (Student 81, 21 years old, man).
- “It is practical for the delivery of tasks as well as the consultation of information” (Student 89, 22 years old, woman).

Due to the COVID-19 pandemic, the teachers of the Clinical Method, Urban Problems and Electromagnetic Prospecting courses used technological advances to build new educational virtual spaces. According to the students, the Learning Management Systems improved the learning process because they are simple and easy to use.

- “Simple and dynamic platform” (Student 5, 21 years old, man).
- “It is accessible and easy to use” (Student 19, 22 years old, man).

Figure 5 shows that the most frequent words about the use of Moodle and Google Classroom in the educational field are: materials (n = 14), platform (n =14), tasks (n =13), activities (n = 11), access (n =10) and organization (n =10).

Figure 5. Word cloud about the Learning Management Systems.
Source: created by the authors

5 DISCUSSION

Distance education plays a fundamental role in order to realize the school activities (Jandric et al., 2020; Qin et al., 2022; Rapanta et al., 2020). In particular, 40.63% of the students think that the use of LMS facilitates much the learning process during the COVID-19 pandemic. For example, Moodle and Google Classroom allowed the realization of the school activities from anywhere. Also, the students of Psychology, Social Work and Geophysics consulted the contents, resources and information of the courses through these technological tools at any time.

On the other hand, the use of Zoom facilitates much (n = 66, 51.56%) the learning process during the COVID-19 pandemic. According to the students of Psychology, Social Work and Geophysics, Zoom facilitated the interaction during the educational process. Therefore, most of the students have a favorable opinion about the use of this technological tool.

5.1 Assimilation of knowledge

Various authors (e.g., Gillingham et al., 2020; Liu et al., 2018; Ruschenpohler & Markic, 2019) mention that the use of technology in the school activities improves the teaching-learning conditions. In particular, 44.53% of the students think that the use of ICTs improves much the assimilation of knowledge. According to the students of Psychology, Social Work and Geophysics, Zoom facilitated the interaction during the educational process. In addition, the use of ICTs improves very much (n = 22, 17.19%) the assimilation of knowledge. Therefore, most of the students (61.72%) have a favorable opinion about this aspect.

Similar to Gende (2020), the use of the Learning Management Systems facilitates the teaching-learning process and organization of new school activities. In particular, Moodle and Google Classroom facilitated the organization of the school activities in the distance modality. The results of machine learning on H1 are higher than 0.040, therefore, the use of the Learning Management Systems (Moodle and Google Classroom) during the COVID-19 pandemic positively influences the assimilation of knowledge. In fact, these Learning Management Systems allowed the delivery of assignments and realization of online exams at the National Autonomous University of Mexico.

The students of Psychology, Social Work and Geophysics consulted the contents, resources and information of the courses through Moodle and Google Classroom at any time. Data science identifies 10 conditions of the PM1. In this predictive model, the career and sex of the students determine how the Learning Management Systems influence the use of ICTs for the assimilation of knowledge.

As Westervelt et al. (2018) indicated, video conferencing systems allow the realization of the teaching-learning process in the distance modality. For example, the students of Clinical Method, Urban Problems and Electromagnetic Prospecting courses used Zoom to ask

questions and solve the academic doubts. The results of machine learning on H2 are higher than 0.390, therefore, the use of Zoom during the COVID-19 pandemic positively influences the assimilation of knowledge.

The use of Zoom improved the communication between the students and teachers of the National Autonomous University of Mexico. Data science identifies 10 conditions of the PM2. In this predictive model, the career and sex of the students determine how Zoom influences the use of ICTs for the assimilation of knowledge. Finally, educational institutions use videoconferencing systems to facilitate the teaching-learning process in the distance modality.

As mentioned by Li et al. (2024), Machine Learning algorithms allow identifying the models to forecast the events. The functions to predict the assimilation of knowledge considering the use of the Learning Management Systems are: $y = 0.056x + 2.199$, $y = 0.041x + 2.254$ and $y = 0.089x + 2.138$. Also, the functions to predict the assimilation of knowledge considering the use of Zoom are: $y = 0.521x + 1.277$, $y = 0.392x + 1.556$ and $y = 0.411x + 1.483$.

5.2 Participation of the students

Various authors (e.g., Castillo-Cuesta et al., 2022; Hetherington et al., 2018; Riopel et al., 2019) explain that students play an active role during the educational process due to the incorporation of technology in the school activities. Due to the COVID-19 pandemic, the teachers of the Clinical Method, Urban Problems and Electromagnetic Prospecting courses used the Learning Management Systems to build new educational virtual spaces. In fact, 32.81% of the students think that the use of ICTs improves much the participation during the educational process. Also, the use of ICTs improves very much (n = 15, 11.72%) the participation during the educational process. Therefore, 44.53% of the students have a favorable opinion on this aspect.

This study shares the ideas of various authors (e.g., Badia et al., 2019; Gende, 2020; Heyde & Siebrits, 2019) about the role of Learning Management Systems to organize creative student-centered activities. The results of machine learning on H3 are higher than 0.069, therefore, the use of the Learning Management Systems during the COVID-19 pandemic positively influences the participation. According to the students, Moodle and Google Classroom improved the learning process because they are simple and easy to use.

Likewise, data science identifies 8 conditions of the PM3. In this predictive model, the career and sex of the students determine how the Learning Management Systems influence the use of ICTs for the participation of the students. In fact, the incorporation of Moodle and Google Classroom facilitated the teaching-learning process at the National Autonomous University of Mexico.

Similar to Heyde and Siebrits (2019), the use of video conferencing systems in the educational field allow the realization of the school activities from anywhere. For example, the teachers of the courses of Clinical Method, Urban Problems and Electromagnetic Prospecting transformed the learning process by incorporating Zoom in the school activities. The results of machine learning on the H4 are higher than 0.110, therefore, the use of Zoom during the COVID-19 pandemic positively influences the participation of the students.

Data science identifies 8 conditions of the PM4. In this predictive model, the career and sex of the students determine how Zoom influences the use of ICTs for the participation of the students. Finally, videoconferencing systems played a fundamental role during the organization and realization of the distance courses.

Shiao et al. (2023) explain that the Deep Learning algorithm allows building the predictive models with great accuracy. The functions to predict the participation considering the use of the Learning Management Systems are: $y = 0.070x + 2.572$, $y = 0.138x + 2.403$ and $y = 0.156x + 2.229$. Also, the functions to predict the participation considering the use of Zoom are: $y = 0.246x + 2.153$, $y = 0.164x + 2.450$ and $y = 0.112x + 2.342$.

According to Li et al. (2024), the decision tree algorithm allows building the predictive models considering the independent and dependent variables. In this study, this Machine Learning algorithm identified 4 models to predict the assimilation of knowledge and participation of the students considering the use of Zoom and Learning Management Systems.

6 CONCLUSION

During the COVID-19 pandemic, teachers are changing the learning process through the creation of new school activities in the distance modality. The results of the deep learning technique indicate that the use of Zoom and the Learning Management Systems positively influences the assimilation of knowledge and participation of the students during the educational process.

This research recommends the incorporation of the Learning Management Systems and Zoom in the educational field in order to create new virtual learning spaces where students have an active role from anywhere. In particular, these technological tools improved the interaction and communication between the students of Psychology, Social Work and Geophysics in the distance modality.

The limitations of this research are the use of two technological tools in the teaching-learning process and incorporation of the Learning Management Systems and Zoom at the higher educational level. Therefore, future research can analyze the impact of these technological tools together with Kahoot, social networks and WhatsApp in middle schools, high schools and universities.

Finally, technology allows the updating of the courses in the distance modality. In particular, Moodle, Google Classroom and Zoom facilitated the organization and implementation of new school activities in the Clinical Method, Urban Problems and Electromagnetic Prospecting courses during the COVID-19 pandemic.

Acknowledgments

This work was supported by UNAM-DGAPA-PAPIME: PE306619 (El Aula del Futuro: SUA de la Facultad de Psicología) and PE102920 (El Aula del Futuro del Instituto de Geofísica).

REFERENCES

Adouani, Y., & Khenissi, M. A. (2024). Investigating computer science students' intentions towards the use of an online educational platform using an extended technology acceptance model (e-TAM): An empirical study at a public university in Tunisia. *Education and Information Technologies*, *29*, 14621-14645. https://doi.org/10.1007/s10639-023-12437-6

Altakhayneh, B. H. (2022). Impact of Using Flipped Classroom Strategy in Developing the Mathematical Thinking of Pre-Service Teachers in Open Education Systems in Jordan. *International Journal of Emerging Technologies in Learning*, *17*(3), 228-244. https://doi.org/10.3991/ijet.v17i03.24973

Amjadi, M. F., Kociubuk, J., & Hollnagel, F. (2024). Zoom Improv is accessible and enhances medical student empathy. *BMC Medical Education*, *24*, 1049. https://doi.org/10.1186/s12909-024-06017-6

Aunimo, L., Kauttonen, J., Vahtola, M. (2024). Combining data from a LMS and a student register for exploring factors affecting study duration. *Journal of Computing in Higher Education*. https://doi.org/10.1007/s12528-024-09414-4

Ayanwale, M. A., Molefi, R. R. & Oyeniran, S. (2024). Analyzing the evolution of machine learning integration in educational research: a bibliometric perspective. *Discover Education*, *3*, 47. https://doi.org/10.1007/s44217-024-00119-5

Badia, A., Martín, D. & Gómez, M. (2019). Teachers' Perceptions of the Use of Moodle Activities and Their Learning Impact in Secondary Education. *Technology, Knowledge and Learning*, *24*, 483-499. https://doi.org/10.1007/s10758-018-9354-3

Ballejos, M. P., Oglesbee, S., Hettema, J. & Sapien, R. (2018). An equivalence study of interview platform: Does videoconference technology impact medical school acceptance rates of different groups? *Advances in Health Sciences Education*, *23*, 601-610. https://doi.org/10.1007/s10459-018-9817-2

Barelli, E., Lodi, M., Branchetti, L., & Levrini, O. (2024). Epistemic Insights as Design Principles for a Teaching-Learning Module on Artificial Intelligence. *Science & Education*. https://doi.org/10.1007/s11191-024-00504-4

Castillo-Cuesta, L., Ochoa-Cueva, C., & Cabrera-Solano, P. (2022). Virtual Workspaces for Enhancing Collaborative Work in EFL Learning: A Case Study in Higher Education. *International Journal of Emerging Technologies in Learning*, *17*(2), 4-18. https://doi.org/10.3991/ijet.v17i02.25937

Chang, J. H., Wang, C. J., Zhong, & H. X. (2024). Artificial intelligence learning platform in a visual programming environment: exploring an artificial intelligence learning model. *Educational technology research and development*, *72*, 997-1024. https://doi.org/10.1007/s11423-023-10323-z

Cirigliano, M. M., Guthrie, C. D., & Pusic, M. V. (2020). Click-level Learning Analytics in an Online Medical Education Learning Platform. *Teaching and Learning in Medicine*, *32*(4), 410-421. https://doi.org/10.1080/10401334.2020.1754216

Eiland, L. S. (2018). Student Perceptions of Active-Learning Strategies Utilized in a Drugs in Pregnancy Elective Delivered Synchronously Across Multiple Campuses. *TechTrends*, *62*, 259-265. https://doi.org/10.1007/s11528-018-0260-2

Gamage, S. H., Ayres, J. R., Behrend, M.B., & Smith, E. J. (2019). Optimising Moodle quizzes for online assessments. *International Journal of STEM Education*, *6*, 1-8. https://doi.org/10.1186/s40594-019-0181-4

Gende, D. (2020). Redesigning assessments for remote learning. *The Physics Teacher*, *58*(6), 440-443. https://doi.org/10.1119/10.0001849

Gillingham, K., Eggleton, K., & Goodyear-Smith, F. (2020). Is Reflective Learning Visible in Online Discussion Forums for Medical Students on General Practice Placements? A Qualitative Study. *Teaching and Learning in Medicine*, *32*(4), 434-441. https://doi.org/10.1080/10401334.2020.1730184

Hetherington, L., Hardman, M., Noakes, J., & Wegerif, R. (2018). Making the case for a material-dialogic approach to science education. *Studies in Science Education*, *54*(2), 141-176. https://doi.org/10.1080/03057267.2019.1598036

Heyde, V. V. & Siebrits, A. (2019). Higher-Order e-Assessment for Physics in the Digital Age Using Saka. *The Physics Teacher*, *57*(1), 32-35. https://doi.org/10.1119/1.5084925

Howard, C. D. & Benedicks, R. (2020). An Industry Liaison for Graduate Learning in Instructional Design. *TechTrends*, *64*, 451-459. https://doi.org/10.1007/s11528-019-00465-4

Ibañez, P., Villalonga, C. & Nuere, L. (2020). Exploring Student Activity with Learning Analytics in the Digital Environments of the Nebrija University. *Technology, Knowledge and Learning*, *25*, 769-787. https://doi.org/10.1007/s10758-019-09419-4

Iyamuremye, A., Niyonzima, F. N., & Mukiza, J. (2024). Utilization of artificial intelligence and machine learning in chemistry education: a critical review. *Discover Education*, *3*, 95. https://doi.org/10.1007/s44217-024-00197-5

Jandric, P., Hayes, D., Truelove, I., & Hayes, S. (2020). Teaching in the Age of Covid-19. *Postdigital Science and Education*, *2*, 1069-1230. https://doi.org/10.1007/s42438-020-00169-6

Knapp, N. F. (2018). Increasing Interaction in a Flipped Online Classroom through Video Conferencing. *TechTrends*, *62*, 618-624. https://doi.org/10.1007/s11528-018-0336-z

Li, S., Huang, X., Wang, & T. Zhen, J. (2024). Using text mining and machine learning to predict reasoning activities from think-aloud transcripts in computer assisted learning. *Journal of Computing in Higher Education*. https://doi.org/10.1007/s12528-024-09404-6

Liu, K., Miller, R., Dickmann, E., & Monday, K. (2018). Virtual Supervision of Student Teachers as a Catalyst of Change for Educational Equity in Rural Areas. *Journal of Formative Design in Learning*, *2*, 8-19. https://doi.org/10.1007/s41686-018-0016-6

Maggio, M. (2020). University teaching practices in the pandemic: from shock to mutation. *Campus Virtuales*, *9*(2), 113-122.

Qin, S., Orchakova, L., Liu, Z. Y., Smirnova, Y., & Tokareva, E. (2022). Using the Learning Management System Modular Object-Oriented Dynamic Learning Environment in Multilingual Education. *International Journal of Emerging Technologies in Learning*, *17*(3), 173-191. https://doi.org/10.3991/ijet.v17i03.25851

Rapanta, C., Botturi, L., Goodyear, P., Guardia, L., & Koole, M. (2020). Online University Teaching During and After the Covid-19 Crisis: Refocusing Teacher Presence and Learning Activity. *Postdigital Science and Education*, *2*, 923-945. https://doi.org/10.1007/s42438-020-00155-y

Ramírez-Montoya, M. S. (2020). Transformación digital e innovación educativa en Latinoamérica en el marco del COVID-19. *Campus Virtuales*, *9*(2), 123-139.

Riopel, M., Nenciovici, L., Potvin, P., Chastenay, P., Charland, P., Sarrasin, J. B., & Masson, S. (2019). Impact of serious games on science learning achievement compared with more conventional instruction: an overview and a meta-analysis. *Studies in Science Education*, *55*(2), 169-214. https://doi.org/10.1080/03057267.2019.1722420

Ruschenpohler, L. & Markic, S. (2019). Self-concept research in science and technology education – theoretical foundation, measurement instruments, and main findings. *Studies in Science Education*, *55*(1), 37-68. https://doi.org/10.1080/03057267.2019.1645533

Salas-Rueda, R. A., Cabrera-Rodríguez, A. E., & Domínguez-Herrera, E. (2024). Use of the flipped classroom and technology in the teaching-learning process about the landscape concept in the High School College. *Atelie Geográfico*, *18*(1), 429-449. https://doi.org/10.5216/ag.v18i1.79052

Shiao, Y. T., Chen, C. H., & Wu, K. F. (2023). Reducing dropout rate through a deep learning model for sustainable education: long-term tracking of learning outcomes of an undergraduate cohort from 2018 to 2021. *Smart Learning Environments*, *10*, 55. https://doi.org/10.1186/s40561-023-00274-6

Westervelt, K. C., Hing, W., McGovern, M. C., Banks, L., Carney, C., Kunker, K., Magoon, A., Sibold, J. & Crane, L. (2018). An online model of international clinical mentoring for novice physical therapists. *Journal of Manual & Manipulative Therapy*, *26*(3), 170-180. https://doi.org/10.1080/10669817.2018.1447789

Wu, D., Guo, Z., & Wang, Y. (2024). Auxiliary analysis of digital platform using internet of things technology in physical education teaching. *Education and Information Technologies*, *29*, 15855-15874. https://doi.org/10.1007/s10639-024-12469-6

Wut, Tm., Shun-mun Wong, H., & Ka-man Sum, C. (2024). Does institution support matter? Blended learning approach in the higher education sector. *Education and Information Technologies*, *29*, 15133–15145. https://doi.org/10.1007/s10639-024-12478-5

Zhai, X., Haudek, K. C., & Ma, W. (2023). Assessing Argumentation Using Machine Learning and Cognitive Diagnostic Modeling. *Research in Science Education*, *53*, 405-424. https://doi.org/10.1007/s11165-022-10062-w

ÚS DE LES TÈCNIQUES D'APRENENTATGE PROFUND I ARBRE DE DECISIÓ PER ANALITZAR LA INCORPORACIÓ DE TECNOLOGIA EN L'ÀMBIT EDUCATIU.

L'objectiu d'aquesta investigació mixta és analitzar la percepció dels estudiants sobre l'ús de Zoom i els Sistemes de Gestió d'Aprenentatge com Moodle i Google Classroom a l'àmbit educatiu durant la pandèmia de COVID-19 considerat ciència de dades. En particular, Zoom facilita la comunicació, la presentació de continguts i la resolució de dubtes. D'altra banda, Moodle i Google Classroom permeten el lliurament de tasques, la consulta d'informació i la realització de fòrums de discussió des de qualsevol lloc. Els participants són 128 estudiants de Psicologia (n = 70, 54,69%), Treball Social (n = 33, 25,78%) i Geofísica (n = 25, 19,53%) que van cursar les carreres de Mètode Clínic, Problemes Urbans i Prospecció Electromagnètica de la Universitat. Universitat Nacional Autònoma de Mèxic durant el cicle escolar 2020. Els resultats de la tècnica d'aprenentatge profund indiquen que l'ús de Zoom i Sistemes de Gestió d'Aprenentatge (Moodle i Google Classroom) durant la pandèmia de COVID-19 influeix positivament en l'assimilació de coneixements i participació dels estudiants. La tècnica de l"arbre de decisió identifica 4 models predictius sobre l"ús d"aquestes eines tecnològiques. Finalment, Zoom, Moodle i Google Classroom permeten transformar el procés d'ensenyament i aprenentatge i actualitzar les activitats escolars durant la pandèmia de COVID-19..

PARAULES CLAU: Tecnologia; TIC; Zoom; LMS; COVID-19; Ciència de dades

USO DE LAS TÉCNICAS DE APRENDIZAJE PROFUNDO Y ÁRBOL DE DECISIÓN PARA ANALIZAR LA INCORPORACIÓN DE TECNOLOGÍA EN EL ÁMBITO EDUCATIVO.

El objetivo de esta investigación mixta es analizar la percepción de los estudiantes sobre el uso de Zoom y los Sistemas de Gestión de Aprendizaje como Moodle y Google Classroom en el ámbito educativo durante la pandemia de COVID-19 considerado ciencia de datos. En particular, Zoom facilita la comunicación, presentación de contenidos y resolución de dudas. Por otro lado, Moodle y Google Classroom permiten la entrega de tareas, consulta de información y realización de foros de discusión desde cualquier lugar. Los participantes son 128 estudiantes de Psicología (n = 70, 54,69%), Trabajo Social (n = 33, 25,78%) y Geofísica (n = 25, 19,53%) que cursaron las carreras de Método Clínico, Problemas Urbanos y Prospección Electromagnética de la Universidad. Universidad Nacional Autónoma de México durante el ciclo escolar 2020. Los resultados de la técnica de aprendizaje profundo indican que el uso de Zoom y Sistemas de Gestión de Aprendizaje (Moodle y Google Classroom) durante la pandemia de COVID-19 influye positivamente en la asimilación de conocimientos y participación de los estudiantes. La técnica del árbol de decisión identifica 4 modelos predictivos sobre el uso de estas herramientas tecnológicas. Finalmente, Zoom, Moodle y Google Classroom permiten transformar el proceso de enseñanza-aprendizaje y actualizar las actividades escolares durante la pandemia de COVID-19.

PALABRAS CLAVE: Tecnología; TIC; Zoom; LMS; COVID-19; Ciencia de datos