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The Collaborative Wall: A Technological Means to Improving the Teaching-Learning Process about Physics

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Nowadays, teachers seek to improve learning conditions and build new educational spaces through technological advances. This mixed research aims to analyse students' perceptions about the use of the collaborative wall in the teaching-learning process for physics, considering data science. The collaborative wall is a web application that allows the participation of the students in the classroom through the dissemination of text and images. The participants are 77 students of the National Preparatory School No. 7 'Ezequiel A. Chávez' who took the course of Physics IV during the 2019 school year. At home, these students searched for and consulted information about the physics of hearing in order to create their infographics collaboratively using the Piktochart software. During the face-to-face sessions, the teacher of the course of Physics IV requested the creation of teams (maximum six members) to carry out the collaborative activities and used the projector to show the collaborative wall. Subsequently, each team uploaded their infographics on the collaborative wall through mobile devices such as tablets and smartphones to initiate the discussion of the Physics of Hearing topics. The results of machine learning (linear regression) indicate that the dissemination of infographics on the collaborative wall positively influences participation in the classroom, students' motivation, and the learning process about the physics of hearing. Data science identifies three predictive models about using the collaborative wall in physics through the decision tree technique. Finally, the collaborative wall facilitates the active role of the students during the face-to-face sessions, communication in the classroom and realisation of the collaborative activities.

Keywords: physics education, collaborative wall, collaborative activities, student opinion, data science

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Zid sodelovanja: tehnološko sredstvo za izboljšanje procesov poučevanja in učenja o fiziki

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Dandanes si učitelji prizadevajo, da bi prek tehnološkega napredka izboljšali učne pogoje in ustvarili nove izobraževalne prostore. Namen te mešane raziskave je ob upoštevanju podatkovne znanosti preučiti dojemanja učencev glede zidu sodelovanja v procesih poučevanja in učenja o fiziki. Zid sodelovanja je spletna aplikacija, ki omogoča udeležbo učencev v učilnici prek razširjanja besedil in slik. Udeležence predstavlja 77 srednješolcev Državne pripravljalne šole št. 7 'Ezequiel A. Chávez', ki so v letu 2019 obiskovali predmet fizika IV. Doma so ti dijaki poiskali in pregledali podatke o fiziki sluha, da bi skupaj ustvarili infografiko, z uporabo programske opreme Piktochart. Izvajalec fizike IV je med osebnimi srečanji pozval, da se oblikujejo skupine (z največ šestimi člani), ki so opravile naloge, in se poslužil projektorja za prikaz zidu sodelovanja. Nato je vsaka skupina naložila svojo infografiko na zid sodelovanja prek prenosne naprave, na primer tablic in pametnih telefonov, to pa za to, da se je lahko začela razprava na temo fizike sluha. Rezultati strojnega učenja (linearna regresija) kažejo, da je nalaganje infografik na zid sodelovanja pozitivno učinkovalo na delo v učilnici, motivacijo učencev in na učni proces o fiziki sluha. Podatkovna znanost prepoznava tri napovedovalne modele o uporabi zidu sodelovanja pri fiziki prek tehnike drevesa odločitev. Ne nazadnje pa zid sodelovanja pripomore k aktivni vlogi učenca med osebnimi srečanji, sporazumevanju v učilnici in k izvedbi skupnih dejavnosti.

Ključne besede: pouk fizike, zid sodelovanja, skupne dejavnosti, mnenje učenca, podatkovna znanost

Introduction

Today, educational institutions use technology to improve the teaching-learning process and organise new school activities (Azodi & Lotfi, 2020; Crouch & Hirshfeld, 2020; Ivić, 2019; Morphew et al., 2020). The use of Information and Communication Technology (ICT) in the educational field allows the personalisation of learning, the development of skills, and the active role of the students (Balalaieva, 2019; McMahon & Walker, 2019; Roldán-Segura et al., 2018; Zaneldin et al., 2019). For example, incorporating mobile devices in school activities facilitates the interaction and participation of the students before, during, and after the face-to-face sessions (Howlett & Waemusa, 2018; Yarahmadzehi & Goodarzi, 2020; Watkins et al., 2019).

The role of teachers in the educational field is changing due to the emergence of new digital tools, educational platforms and technological applications (Aznar-Díaz et al., 2019; Bilgic & Tuzun, 2020; Bosco et al., 2019; Bravo et al., 2019; Mäkipää et al., 2021). ICT facilitates the organisation of creative school activities inside and outside the classroom (De-Oscar & Santos-Gomes, 2019; Korhonen et al., 2021; Pulgar et al., 2020; Salas-Rueda, 2020).

In the field of physics, teachers have updated the school activities through the computer (Roldán-Segura et al., 2018), mobile devices (Di-Laccio et al., 2017), films(Quirantes-Sierra et al., 2011), digital games (Lion & Perosi, 2019), digital tools (Bravo et al., 2019) and videos (Vera et al., 2015). At Charles University in the Czech Republic, the use of the Interactive Physics Laboratory facilitated the active role of the students, collaborative work and assimilation of knowledge about electrostatics, motion under gravity, the magnetic field of solenoids, optics, oscillations and rigid body mechanics, rotating frames of reference, and thermodynamics (Snětinová et al., 2018). In the same way, the physics course students repaired a thermometer to facilitate the learning process about the principles of Galileo (Kireš, 2018). Repnik and Ambrožič (2018) organised and carried out collaborative activities about the centre of mass to encourage the active participation of the students during the face-to-face sessions.

Interactive virtual walls such as Padlet allow students to acquire a primary role during the teaching-learning process through exchanging ideas (DeWitt et al., 2015; Lyonsab et al., 2021; Rashid et al., 2019). In the English language course, the use of Padlet facilitated the participation of the students during the face-to-face sessions and improved academic performance (Zou & Xie, 2019). Similarly, the incorporation of Padlet in a foreign language course increased the students' motivation during the learning process, developed writing skills, and improved communication in the classroom (Rashid et al., 2019).

Interactive virtual walls are transforming the functions of the students during face-to-face sessions (DeWitt et al., 2015; Lyonsab et al., 2021; Zou & Xie, 2019). For example, Padlet allows efficient communication between the participants of the educational process through mobile devices (Sangeetha, 2016; Zou & Xie, 2019). The benefits of using interactive virtual walls in the educational field are the autonomy of the students during the learning process and the interaction of the participants in the classroom (Lyonsab et al., 2021; Rashid et al., 2019; Sangeetha, 2016).

Currently, the teachers of physics courses are using technological advances to build new educational spaces, facilitate the learning process, and promote the active role of students. For example, the collaborative wall is a web application that allows the participation of the students in the classroom through the dissemination of text and images. In this study, the students of the National Preparatory School No. 7 'Ezequiel A. Chávez' presented infographics about the physics of hearing on the collaborative wall in order to carry out the discussion of the topics related to the waves, sound phenomena, hearing, energy transfer and Doppler Effect during the face-to-face sessions.

Therefore, this mixed research aims to analyse students' perceptions about using the collaborative wall in the teaching-learning process on physics with the use of data science. The research questions are:

1. What is the impact of the use of the collaborative wall in the teaching-learning process in physics?
2. What are the predictive models about the collaborative wall, participation in the classroom, motivation of the students and learning process about the Physics of Hearing?
3. What are the students' perceptions about disseminating infographics on the collaborative wall?

Literature review

Use of technology in the educational process about Physics

The use of technological tools, educational software, and web applications is transforming the teaching-learning process in physics (Crouch & Hirshfeld, 2020; Di-Laccio et al., 2017; Roldán-Segura et al., 2018). For example, the students of physics courses use ICT to facilitate the assimilation of knowledge, development of skills, and participation inside and outside the classroom (Bravo et al., 2019; Crouch & Hirshfeld, 2020; Morphew et al., 2020).

In secondary schools, teachers use technological advances to build new learning spaces in physics (Gambari & Yusuf, 2016; Roldán-Segura et al., 2018). The students used mobile devices to facilitate the assimilation of knowledge and develop computer skills (Roldán-Segura et al., 2018). The results regarding the use of this technology reveal an increase in academic performance, the development of skills, and the active role of the students during the learning process (Roldán-Segura et al., 2018).

At the University of Granada, the students improved their academic performance in the physics course by consulting audiovisual content (Quirantes-Sierra et al., 2011). In particular, the use of films facilitated the learning about physics, developed the skills and increased the students' motivation during the face-to-face sessions (Quirantes-Sierra et al., 2011).

Educational institutions use technological advances such as mobile devices to update the physics courses (Di-Laccio et al., 2017; Roldán-Segura et al., 2018; Tracey et al., 2018). For example, the use of smartphones facilitated the assimilation of knowledge about the Doppler effect and improved the participation of the students in the classroom (Di-Laccio et al., 2017).

Technological tools enable the construction of new educational spaces in physics classes (Bravo et al., 2019). For example, the CmapTools application facilitated the understanding of the phenomenon of electromagnetic induction through the development of conceptual diagrams (Bravo et al., 2019).

Likewise, the design and production of videos enable updating the educational field activities (Cakiroglu & Yilmaz, 2017; Iskru & Schulz, 2020; Vera et al., 2015). In the physics course, the use of the videos facilitated the learning process about the phenomenon of free fall, increased motivation, and improved the participation of the students (Vera et al., 2015).

Finally, technological advances such as videos, digital tools and web applications are changing the organisation and implementation of school activities in the field of physics (Morphew et al., 2020; Roldán-Segura et al., 2018; Vera et al., 2015). The use of ICT in physics courses facilitates the active role of the students inside and outside the classroom (Bravo et al., 2019; Di-Laccio et al., 2017; Romero et al., 2020).

Use of the virtual wall and infographics in the educational field

Today, technology is transforming the realisation of school activities inside and outside the classroom (Arenas-Arredondo et al., 2021; De-Witt & Koh, 2020). In particular, virtual walls such as Padlet, Jamboard, and the collaborative wall enable the exchange of ideas before, during, and after the face-to-face sessions (De-Witt & Koh, 2020; Fadhilawati et al., 2020; Kharis et al., 2020).

In India, the use of Padlet and Edmodo improved the assimilation of knowledge, facilitated the realisation of collaborative activities, and developed the writing skills of the students in an English Language course (Sangeetha, 2016). Similarly, the students of a German language course used this virtual wall to improve their academic performance and develop their writing skills (Kharis et al., 2020).

The benefits of using virtual walls are increasing the motivation and active role of the students during the teaching-learning process (Fadhilawati et al., 2020; Kharis et al., 2020). For example, the students of an English language course used Padlet to develop their writing skills and actively participate in the classroom (Fadhilawati et al., 2020). Furthermore, the students of a business finance course applied, shared, and acquired new knowledge through an interactive virtual wall (De-Witt & Koh, 2020).

Virtual walls have improved the teaching-learning conditions in English language courses (Fadhilawati et al., 2020; Sangeetha, 2016), a German language course (Kharis et al., 2020) and a business finance course (De-Witt & Koh, 2020) by aiding in exchanging ideas and conducting the discussions. Also, this technological tool facilitated the organisation of collaborative activities and the construction of new learning spaces (De-Witt & Koh, 2020; Kharis et al., 2020)

At the same time, educational institutions use infographics to facilitate the assimilation of knowledge through the combination of text and images (Arenas-Arredondo et al., 2021; González, 2018; Muñoz-García, 2014). According to Arenas-Arredondo et al. (2021), incorporating infographics in the school activities improved the understanding of the topics, including specific sciences, social communication, education, informatics, engineering, health and tourism.

The benefits of infographics in the educational field are the creation of new school content, increasing motivation during the teaching-learning process, and disseminating information through images and text (Arenas-Arredondo et al., 2021; Dolz, 2020; Muñoz-García, 2014). In the field of electronics, the use of infographics improved the teaching-learning process about Boolean Algebra, developed the skills and increased the students' motivation during the realisation of the school activities (Salas-Rueda, 2015).

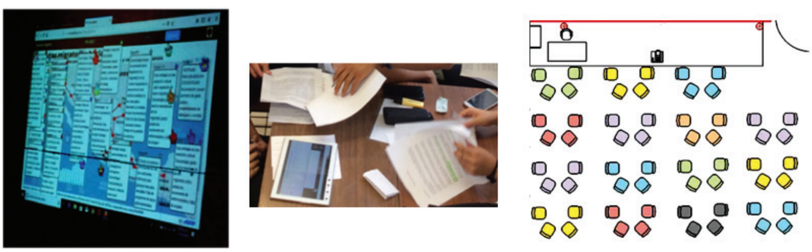
At the postgraduate level, teachers used infographics to increase the motivation and satisfaction of the students, to provide information, and to facilitate the assimilation of knowledge (Dolz, 2020). In the same way, the students of a biology course improved their understanding of animal and plant cells by consulting infographics (González, 2018).

Method

The Institute of Applied Sciences and Technology at the National Autonomous University of Mexico built a collaborative wall to promote the active role of the students during face-to-face sessions. The particular aims of this research are: (1) analyse the impact of the collaborative wall on participation during the face-to-face sessions, the motivation of the students, and the learning process about the physics of hearing (2) analyse the perceptions of the students about the use of the collaborative wall in the educational field and (3) identify the predictive models on the collaborative wall in the unit entitled 'Sound: The ear as a hearing instrument'.

The collaborative wall is a web application that allows the participation of the students in the classroom through the dissemination of text and images (See Figure 1). During the face-to-face sessions, the students use mobile devices such as tablets and smartphones to enter the collaborative wall.

Figure 1
Example about the use of Collaborative Wall



Participants

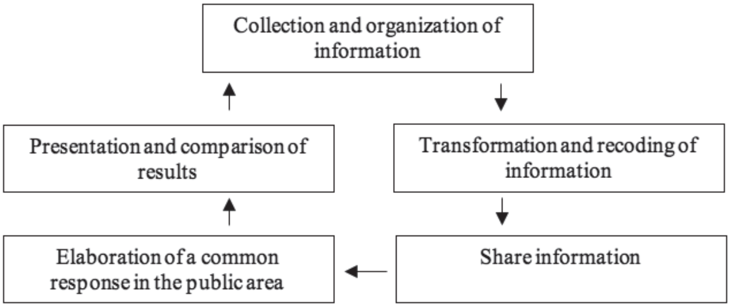
The participants are 77 students (30 male and 47 female) of the National Preparatory School No. 7 'Ezequiel A. Chávez' who took the course of Physics IV during the 2019 school year; the average age of the participants is 17.18 years.

Procedure

The National Autonomous University of Mexico offered the 'Diploma Classroom' of the Future' in the 2019 school year to improve the teaching-learning conditions through the use of the pedagogical model proposed by Gamboa (2015) and technology (See Figure 2). During Module 3 of this diploma, the teachers used the collaborative wall to facilitate the participation of the students in the classroom.

Figure 2

Techno-pedagogical model proposed



Note. Adapted from Gamboa-Rodríguez (2015).

At home, the students searched for and consulted the information about the physics of hearing to create their infographics using the Piktochart software collaboratively. During the face-to-face sessions, the teacher of the course of Physics IV requested the creation of teams (maximum six members) to show the collaborative wall on the projector and carry out the collaborative activities, such as the presentation and exchange of ideas about the waves, sound phenomena, hearing, energy transfer and Doppler Effect.

Subsequently, each team uploaded their infographics on the collaborative wall through mobile devices such as tablets and smartphones to initiate the discussion about the physics of hearing topics. Table 1 shows the analysis of the educational context.

Table 1
Educational context

No.	Aspect	Element	Description
1	Analysis	Course	Physics IV
		Problem	The students have difficulty assimilating and understanding the topics about the Physics of Hearing
2	Design	Learning objectives	Describe and discuss the topic about the waves
			Describe, discuss and explain the topic about the sound phenomena
			Describe, discuss, explain and interpret the topic about the hearing and energy transfer
			Describe, discuss, explain, interpret and examine the topic about the Doppler effect
		Incorporation of technology in school activities	Mobile devices such as tablet and smartphone
			Use of the Piktochart software to create the infographic
			Collaborative wall
3	Development	Before the class	At home, the students searched for and consulted the information about the Physics of Hearing in order to create their infographics using the Piktochart software collaboratively
		During the class	During the face-to-face sessions, the teacher of the Physics IV course requested the creation of teams (maximum 6 members) to carry out the collaborative activities and used the projector to show the collaborative wall. Subsequently, each team uploaded their infographics on the collaborative wall through mobile devices such as tablets and smartphones in order to initiate the discussion about the Physics of Hearing topics
4	Implementation	Unit	Sound: The ear as a hearing instrument

Technological advances allow the construction of new educational spaces where the students actively participate during the learning process (Alshammari, 2020; Bursa & Cengelci-Kose, 2020; Elvis-Mbiydzenyuy, 2020). Therefore, the hypothesis about the collaborative wall and participation of the students is:

- Hypothesis 1 (H1): The dissemination of infographics on the collaborative wall positively influences the participation of the students in the classroom.

  Educational institutions and teachers use ICT to increase students' motivation during the learning process (Agormedah et al., 2020; Banafshi et al., 2020). Therefore, the hypothesis about the collaborative wall and motivation of the students in the classroom is:

- Hypothesis 2 (H2): The dissemination of infographics on the collaborative wall positively influences the students' motivation.
  Incorporating technological advances into school activities improves the teaching-learning conditions (Akay & Koral-Gumusoglu, 2020; Carr, 2020; Sabiri, 2020). Therefore, the hypothesis about the collaborative wall and learning process during the realisation of activities in the classroom is:
- Hypothesis 3 (H3): The dissemination of infographics on the collaborative wall positively influences the learning process about the Physics of Hearing

In contrast, the predictive models about the use of the collaborative wall in the course of Physics IV are:

- Predictive Model 1 (PM1) about the dissemination of infographics on the collaborative wall and participation of the students in the classroom
- Predictive Model 2 (PM2) about the dissemination of infographics on the collaborative wall and motivation of the students
- Predictive Model 3 (PM3) about disseminating infographics on the collaborative wall and learning process about the Physics of Hearing.

Data collection

At the end of the 'Sound: The ear as a hearing instrument' unit, the students of the course of Physics IV answered the questionnaire about the use of the collaborative wall (See Table 2).

Table 2

Questionnaire about the use of the collaborative wall

No.	Variable	Dimension	Question	Answer	n	%
1	Profile of the students	Sex	1. Indicate your sex	Male	30	38.96
				Female	47	61.04
		Age	2. Indicate your age	16 years	8	10.39
				17 years	48	62.34
				18 years	20	25.97
				19 years	1	1.30
2	Collaborative wall	Dissemination of infographics	3. The collaborative wall facilitates the dissemination of infographics	Very much (1)	51	66.23
				Much (2)	16	20.78
				Little (3)	7	9.09
				Very little (4)	3	3.90
		Participation of the students in the classroom	4. The use of the collaborative wall improves the participation of the students in the classroom	Very much (1)	49	63.64
				Much (2)	15	19.48
				Little (3)	9	11.69
				Very little (4)	4	5.19
		Motivation of the students	5. The use of the collaborative wall improves the motivation of the students	Very much (1)	43	55.84
				Much (2)	23	29.87
				Little (3)	9	11.69
				Very little (4)	2	2.60
		Learning process	6. The use of the collaborative wall improves the learning process about the Physics of Hearing	Very much (1)	55	71.43
				Much (2)	17	22.08
				Little (3)	3	3.90
				Very little (4)	2	2.60
3	Student perception	Use of collaborative wall	7. What is your opinion about the use of the collaborative wall during the learning process?	Open	-	-

The values of Load Factor (> .500), Cronbach's Alpha (> .600) and Composite Reliability (> .700) are necessary to validate the questionnaire. Table 3 shows that the values of the Load Factor (> .540), Cronbach's Alpha (> .690) and Composite Reliability (> .820) enable validating the questionnaire about the collaborative wall.

Table 3

Validation of the questionnaire about the collaborative wall

Variable	Dimension	Load Factor	Cronbach's Alpha	Average Variance Extracted	Composite Reliability
Collaborative wall	Dissemination of infographics	.795	.695	.543	.822
	Participation of the students in the classroom	.747			
	Motivation of the students	.541			
	Learning process	.831			

Data analysis

Data analysis was performed using the Rapidminer tool and WordCloud application. The Rapidminer tool allows the calculation of linear regressions (machine learning) to evaluate the research hypotheses about the use of the collaborative wall in the course of Physics IV and build the predictive models.

The training section (50%, 60%, 70% and 80% of the sample) allows calculating the linear regressions, and the evaluation section (50%, 40%, 30% and 20% of the sample) allows identifying the accuracy of these linear regressions employing the squared error, which enables knowing the precision of the linear function in order to predict the behaviour of the events (Shalev-Shwartz & Ben, 2014).

According to Anderson et al. (2012), the t-test enables identifying the relationship between the variables of the simple linear regression. In particular, if the value of p is less than 0.05, then the variables have a significant relationship (Anderson et al., 2012).

The information about the student's profile (sex and age) and collaborative wall (dissemination of infographics, participation in the classroom, motivation of the students and learning process) enables the construction of the predictive models by means of the decision tree technique. In contrast, the WordCloud application allows evaluating the students' perception about the use of the collaborative wall through the frequency of words.

Results

The collaborative wall facilitates very much (n = 51, 66.23%), much (n = 16, 20.78%), little (n = 7, 9.09%) and very little (n = 3, 3.90%) the dissemination of infographics (See Table 2). The machine learning results indicate that the dissemination of infographics on the collaborative wall positively influences the participation in the classroom, motivation of the students and learning process about the Physics of Hearing (See Table 4).

Table 4
Results of machine learning

Hypothesis	Training	Linear regression	Conclusion	t-value	p-value	Error squared
H1: Dissemination of infographics on the collaborative wall→ participation in the classroom	50%	y = .528x + .764	Accepted: .528	3.134	.000	.692
	60%	y = .589x + .689	Accepted: .589	4.065	.000	.744
	70%	y = .541x + .741	Accepted: .541	3.996	.000	.720
	80%	y = .493x + .799	Accepted: .493	4.180	.000	.802
H2: Dissemination of infographics on the collaborative wall→ motivation of the students	50%	y = .545x + .712	Accepted: .545	4.411	.000	.604
	60%	y = .535x + .685	Accepted: .535	4.813	.000	.600
	70%	y = .533x + .661	Accepted: .533	5.368	.000	.669
	80%	y = .485x + .732	Accepted: .485	5.487	.000	.733
H3: Dissemination of infographics on the collaborative wall→ learning process	50%	y = .713x + .458	Accepted: .713	6.687	.000	.694
	60%	y = .634x + .512	Accepted: .634	6.437	.000	.638
	70%	y = .611x + .504	Accepted: .611	6.798	.000	.670
	80%	y = .485x + .699	Accepted: .485	5.522	.000	.497

Participation in the classroom

The use of the collaborative wall improves very much (n = 49, 63.64%), much (n = 15, 19.48%), little (n = 9, 11.69%) and very little (n = 4, 5.19%) the participation of the students in the classroom (See Table 2). The results of machine learning with 50% (.528, t-value = 3.134, p-value =.000), 60% (.589, t-value = 4.065, p-value =.000), 70% (.541, t-value = 3.996, p-value = .000) and 80% (.493, t-value = 4.180, p-value = .000) of training indicate that H1 is accepted (See Table 4). Therefore, the dissemination of infographics on the collaborative wall positively influences the participation of the students in the classroom.

Table 5 shows 10 conditions of the PM1 about the use of the collaborative wall with an accuracy of 72.73%. For example, if the student thinks that the collaborative wall very much facilitates the dissemination of infographics and has an age ≤ 18.5 years, then the use of the collaborative wall very much improves the participation of the students in the classroom. Also, if the student thinks that the collaborative wall much facilitates the dissemination of infographics, is male and has an age ≤ 17.5 years, the use of the collaborative wall much improves the participation of the students in the classroom.

Table 5

Conditions of the PM1

No.	Collaborative wall → dissemination of infographics	Sex	Age	Collaborative wall → participation in the classroom
1	Very much	-	> 18.5 years	Very little
2	Very much	-	≤ 18.5 years	Very much
3	Much	Male	> 17.5 years	Very much
4	Much	Male	≤ 17.5 years	Much
5	Much	Female	> 17.5 years	Much
6	Much	Female	≤ 17.5 years	Very much
7	Little	Male	≤ 17.5 years	Very much
8	Little	Female	≤ 17.5 years	Little
9	Little	-	> 17.5 years	Very little
10	Very little	-	-	Much

Motivation of the students

The use of the collaborative wall improves very much (n = 43, 55.84%), much (n = 23, 29.87%), little (n = 9, 11.69%) and very little (n = 2, 2.60%) the motivation of the students (See Table 2). The results of machine learning with 50% (.545, t-value = 4.411, p-value = .000), 60% (.535, t-value = 4.813, p-value = .000), 70% (.533, t-value = 5.368, p-value = .000) and 80% (.485, t-value = 5.487, p-value = .000) of training indicate that H2 is accepted (See Table 4). Therefore, the dissemination of infographics on the collaborative wall positively influences the students' motivation.

Table 6 shows nine conditions of the PM2 about the use of the collaborative wall with an accuracy of 68.83%. For example, if the student thinks that the collaborative wall very much facilitates the dissemination of infographics and has an age ≤ 17.5 years, then the use of the collaborative wall very much improves the students' motivation. Also, if the student thinks that the collaborative wall much facilitates the dissemination of infographics and is female, then the use of the collaborative wall much improves the students' motivation.

Table 6

Conditions of the PM2

No.	Collaborative wall → dissemination of infographics	Sex	Age	Collaborative wall → motivation of the students
1	Very much	-	≤ 17.5 years	Very much
2	Very much	Male	> 17.5 years	Much
3	Very much	Female	> 17.5 years	Very much
4	Much	Male	-	Very much
5	Much	Female	-	Much
6	Little	-	≤ 16.5 years	Much
7	Little	Male	> 16.5 years	Very much
8	Little	Female	> 16.5 years	Little
9	Very little	-	-	Very much

Learning process

The use of the collaborative wall improves very much (n = 55, 71.43%), much (n = 17, 22.08%), little (n = 3, 3.90%) and very little (n = 2, 2.60%) the learning process about the Physics of Hearing (See Table 2). The results of machine learning with 50% (.713, t-value = 6.687, p-value = .000), 60% (.634, t-value = 6.437, p-value = .000), 70% (.611, t-value = 6.798, p-value = .000) and 80% (.485, t-value = 5.522, p-value = .000) of training indicate that H3 is accepted (See Table 4). Therefore, the dissemination of infographics on the collaborative wall positively influences the learning process about the physics of hearing.

Table 7 shows seven conditions of the PM3 about the use of the collaborative wall with an accuracy of 77.92%. For example, if the student thinks that the collaborative wall very much facilitates the dissemination of infographics, is female and has an age ≤ 16.5 years, then the use of the collaborative wall very much improves the learning process about the physics of hearing. Also, if the student thinks that the collaborative wall much facilitates the dissemination of infographics, then the use of the collaborative wall very much improves the learning process about the physics of hearing.

Table 7
Conditions of the PM3

No.	Collaborative wall → dissemination of infographics	Sex	Age	Collaborative wall → learning process
1	Very much	-	> 16.5 years	Very much
2	Very much	Male	≤ 16.5 years	Much
3	Very much	Female	≤ 16.5 years	Very much
4	Much	-	-	Very much
5	Little	-	> 17.5 years	Very little
6	Little	-	≤ 17.5 years	Much
7	Very little	-	-	Very much

Perception of the students

Technological advances enable organising new activities during the face-to-face sessions. In the Physics IV course, the students actively participated in the classroom through the collaborative wall.

- 'We showed our work in an easier way. I understood faster and better' (Student 4, male, 16 years old).
- 'It allowed making a comparison between the different works of the group' (Student 22, male, 16 years old).

Web applications enable the active role of the students during the teaching-learning process. According to the students of the Physics IV course, the collaborative wall is easy to use.

- 'It is easy to use and is very attractive. Also, this application allowed the interaction of several friends at the same time' (Student 26, male, 17 years old).
- 'It's easy and fast' (Student 32, male, 18 years old).

Technology facilitates the creation of new virtual spaces that improve the learning process. In particular, the collaborative wall improved the teaching-learning conditions and facilitated the assimilation of knowledge through the dissemination of infographics.

- 'It was a very useful tool for learning' (Student 37, female, 18 years old).
- 'We better understood the course topics with the application' (Student 42, female, 17 years old).

Teachers use technology to achieve the active role of the students during face-to-face sessions. For example, the collaborative wall facilitated the realisation of creative activities in the classroom.

- 'It was interesting and allowed working creatively and productively' (Student 11, woman, 17 years old).
- 'We show the homework. It is less boring and more practical' (Student 54, female, 17 years old).

Finally, incorporating the collaborative wall into the teaching-learning process on physics increased the students' motivation and enabled sharing the information in the classroom.

- 'The class is less boring' (Student 7, female, 17 years old).
- 'The application allows sharing information' (Student 29, female, 17 years old).

The WordCloud application analyses the answers to the question: 'What is your opinion about the use of the collaborative wall during the learning process?' by identifying the words that students mention most frequently. Figure 3 shows the word cloud about the use of the collaborative wall. The most common words are 'better', 'organisation', 'use', 'topics', 'time', 'way', 'ideas', 'team', 'faster', 'new', 'class', and 'understand'. Therefore, the perception of students about the incorporation of this technological tool in the educational field is strongly related to the words: 'time', 'better', 'use' and 'organisation'.

Figure 3
Word cloud about the use of the collaborative wall

Discussion

Today, teachers are creating and implementing new school activities through technology (Cutri & Mena, 2020; Lee, 2020; Yasar, 2020). In the Physics IV course, educators incorporated the collaborative wall in the 'Sound: The ear as a hearing instrument' unit to improve the teaching-learning conditions.

According to Arenas-Arredondo et al. (2021), the use of infographics in school activities improved the teaching-learning process. In particular, the students of the National Preparatory School No. 7 'Ezequiel A. Chávez' used the Piktochart software to create their infographics about the waves, sound phenomena, hearing, energy transfer, and the Doppler Effect.

Likewise, virtual walls allow the construction of new educational spaces (De-Witt & Koh, 2020; Fadhilawati et al., 2020; Kharis et al., 2020). For example, 66.23% of the students (n = 51) think that the collaborative wall very much facilitates the dissemination of infographics. Also, an analysis showed that the collaborative wall much facilitates (n = 16, 20.78%) the dissemination of infographics. Therefore, the majority of the students (87.01%) have a favourable opinion about this aspect.

Participation in the classroom

Several authors (e.g., Adam, 2020; Okkan & Aydin, 2020; Tilak & Glassman, 2020) mention that the incorporation of digital tools allows the active role of the students at any time. In particular, virtual walls enable active participation in the classroom through the exchange of ideas and discussion of topics (De-Witt & Koh, 2020; Fadhilawati et al., 2020; Kharis et al., 2020). In the Physics course, the students used the collaborative wall to exchange ideas and discuss waves, sound phenomena, hearing, energy transfer, and the Doppler Effect.

Similar to De-Witt and Koh (2020), the incorporation of the interactive virtual wall called Padlet in the Business Finance course facilitated the active role of the students during the face-to-face sessions. Most of the students (n = 49, 63.64%) think that the use of the collaborative wall very much improves the participation of the students in the classroom. Also, the use of the collaborative wall much improves (n = 15, 19.48%) the participation of the students in the classroom. Therefore, the majority of the students (83.12%) have favourable perceptions about the use of this virtual wall.

This research shares the ideas of various authors (e.g., De-Witt & Koh, 2020; Fadhilawati et al., 2020) about the use of virtual walls to promote the active role of the students during the teaching-learning process. The results of machine learning results about H1 are greater than .490; therefore, the dissemination of infographics on the collaborative wall positively influences the participation of the students in the classroom.

Data science enables the identification of ten conditions of the PM1 with an accuracy of 72.73%. In this predictive model, the age and sex of the students determine how the dissemination of infographics on the collaborative wall influences the participation of the students. The decision tree technique identifies four conditions in which the use of the collaborative wall very much improves the participation of the students in the classroom. For example, if the student thinks that the collaborative wall very much facilitates the dissemination of infographics and has an age of ≤ 18.5 years, then the use of the collaborative wall very much improves the participation of the students in the classroom. In contrast, the sex of the students determines six conditions of the PM1. For example, if the student thinks that the collaborative wall much facilitates the dissemination of infographics, is male, and has an age ≤ 17.5 years, then the collaborative wall much improves the participation of the students in the classroom.

Motivation of the students

This research shares the ideas of various authors (e.g., Bozna & Yuzer, 2020; Lee, 2020; Tilak & Glassman, 2020) about the use of technology to increase students' motivation. According to Zou and Xie (2019), the virtual wall facilitated the construction of educational spaces where the students increased their motivation during the teaching-learning process.

In a German language course, the students increased their motivation through the use of Padlet in the classroom (Kharis et al., 2020). In the same way, 55.84% of the students ($n = 43$) think that the use of the collaborative wall very much improves their motivation in the 'Sound: The ear as a hearing instrument' unit. Likewise, quantitative data reveals that the use of the collaborative wall much improves ($n = 23$, 29.87%) the motivation of these students. Therefore, the majority of students (85.71%) have a favourable perception regarding the use of this virtual wall.

As mentioned by Fadhilawati et al. (2020), the incorporation of virtual walls in the educational field favours the creation of new spaces for learning and teaching. The results of machine learning about H2 are greater than 0.480; therefore, the dissemination of infographics on the collaborative wall positively influences the students' motivation.

Data science enables the identification of nine conditions of the PM2 with an accuracy of 68.83%.In this predictive model, the age and sex of the students determine how the dissemination of infographics on the collaborative wall influences their motivation. The decision tree technique identifies five conditions where the use of the collaborative wall very much improves the students' motivation. For example, if the student thinks that the collaborative wall very much facilitates the dissemination of infographics and has an age ≤ 17.5 years, then the use of the collaborative wall very much improves the students' motivation. In contrast, the sex of the students determines six conditions of the PM2. For example, if the student thinks that the collaborative wall much facilitates the dissemination of infographics and is female, then the use of the collaborative wall much improves the motivation of the students.

Learning process

Teachers use web applications and technological tools to facilitate the learning process (Adam, 2020; Cutri & Mena, 2020; Erarslan & Arslan, 2020). As Fadhilawati et al. (2020) indicated, virtual walls improved the assimilation of knowledge and developed the skills of the students. In particular, the incorporation of the collaborative wall in the National Preparatory School No. 7 'Ezequiel A. Chávez' improved the teaching-learning conditions about the waves, sound phenomena, hearing, energy transfer and Doppler Effect.

The use of virtual walls improved the teaching-learning conditions in the English language course (Fadhilawati et al., 2020; Sangeetha, 2016), German language course (Kharis et al., 2020) and business finance course (De-Witt & Koh, 2020) by exchanging the ideas and conducting the discussions. In particular, 71.43% of the students ($n = 55$) think that the use of the collaborative wall very much improves the learning process about the physics of hearing. Likewise, the use of the collaborative wall much improves ($n = 17$, 22.08%) the learning process about the physics of hearing. Therefore, the majority of the students (93.51%) have a favourable perception of the use of this virtual wall.

Various authors (e.g., De-Witt & Koh, 2020; Fadhilawati et al., 2020; Kharis et al., 2020) explain that technological advances such as the virtual wall favour learning inside and outside the classroom. The results of machine learning about H3 are higher than .480; therefore, the dissemination of infographics on the collaborative wall positively influences the learning process about the physics of hearing.

Data science enables the identification of seven conditions of the PM3 with an accuracy of 77.92%. In this predictive model, the age and sex of the students determine how the dissemination of infographics on the collaborative wall influences the learning process. The decision tree technique identifies four conditions in which the use of the collaborative wall very much improves the learning process about the physics of hearing. For example, if the student thinks that the collaborative wall much facilitates the dissemination of infographics, then the use of the collaborative wall very much improves the learning process about the physics of hearing. In contrast, the sex of the students determines two conditions of the PM3. For example, if the student thinks that the collaborative wall facilitates the dissemination of infographics very much, is female and has an age ≤ 16.5 years, then the use of the collaborative wall very much improves the learning process about the physics of hearing.

Perception of the students

In the Physics IV course, the students actively participated in the classroom through the collaborative wall. This web application improved the teaching-learning conditions, facilitated the assimilation of knowledge through the dissemination of infographics and allowed the realisation of creative activities during the face-to-face sessions.

Furthermore, the incorporation of the collaborative wall in the teaching-learning process about physics increased the students' motivation and allowed sharing the information in the classroom.

Conclusion

Educational institutions use technological advances to transform the role of the students during the learning process and improve the teaching conditions. For example, the collaborative wall is a web application that allows the participation of the students in the classroom through the dissemination of text and images. The results of machine learning indicate that the dissemination of infographics on the collaborative wall positively influences the participation in the classroom, motivation of the students and learning process about the physics of hearing. Data science enables the identification of three predictive models about the use of the collaborative wall in the physics classroom.

The limitations of this research are the size of the sample, the use of the collaborative wall during the learning process solely about the physics of hearing and the perceptions of the students. Therefore, future research may analyse the use of the collaborative wall in other topics related to Physics. In addition, an inferential statistical analysis should be used to identify the differences related to the incorporation of this technological tool in the teaching-learning process.

This research recommends the use of the collaborative wall because this web application facilitates the active role of the students during the face-to-face sessions, communication in the classroom and realisation of creative school activities. In the Physics IV course, the incorporation of the collaborative wall in the school activities improved the teaching-learning conditions about the waves, sound phenomena, hearing, energy transfer and Doppler Effect.

Physics is an experimental subject; therefore, educators can use simulators, social networks, web applications, third-dimensional tools to improve the teaching-learning conditions. Finally, teachers can build new educational spaces through technological advances. In particular, the collaborative wall allowed the students of the National Preparatory School No. 7 'Ezequiel A. Chávez' to have the main role during the learning process about the Physics of Hearing.

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