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TPACK: Technological, Pedagogical and Content Model Necessary to Improve the Educational Process on Mathematics through a Web Application?

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ABSTRACT

This quantitative research aims to analyze the design and implementation of the Web Application on the educational process of the Linear Function (WALF) considering the TPACK (Technological Pedagogical and Content Knowledge) model and data science. The sample consists of 45 students who studied the Basic Math course at a Mexican university during the 2015 school year. The TPACK model allows the planning and organization of WALF through technological knowledge (HTML and PHP languages), content knowledge (formulas on the linear function and slope) and pedagogical knowledge (data simulation). The results of machine learning (linear regression) with 50%, 60% and 70% of training indicate that the contents of WALF influence the assimilation of knowledge about the identification and evaluation of the linear function. Data science identifies 2 predictive models on the use of WALF in the field of mathematics by means of the decision tree technique. Finally, the TPACK model facilitates the implementation of technological tools and construction of educational virtual spaces through technological, content and pedagogical knowledge.

Keywords: learning, educational technology, TPACK model, data science, higher education

INTRODUCTION

Universities are incorporating digital tools, technological applications and web platforms in school activities with the purpose of improving teaching-learning conditions (Cabero-Almenara, Arancibia, & Prete, 2019; Han, Wang, & Jiang, 2019). In fact, the use of technology inside and outside the classroom is causing the emergence of new methodologies and educational models (Agreda-Montoro, Ortiz-Colón, Rodríguez-Moreno, & Steffens, 2019; Salas-Rueda, Salas-Rueda, & Salas-Rueda, 2019).

Today, teachers are transforming the educational process through the selection, organization and construction of virtual spaces for learning and teaching (Cejas-León, Navío-Gámez, & Barroso-Osuna, 2016; Fathelrahman, 2019; Zhang, Lou, Zhang, & Zhang, 2019). In fact, Information and Communication Technologies (ICT) are transforming the planning and implementation of school activities (Kwon, Park, Shin, & Chang, 2019; Shah & Cheng, 2019; Zhu, Herring, & Bonk, 2019). For example, the ERPAG application facilitates the assimilation of knowledge and development of skills in computer courses (Salas-Rueda & Vázquez-Estupiñán, 2017).

Teachers need to develop the technological and pedagogical competences to achieve a successful incorporation of digital tools in the teaching-learning process (Cejas-León, Navío-Gámez, & Barroso-Osuna, 2016). For example, the TPACK model facilitates the integration of digital tools and media in the teaching-

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learning process considering the pedagogical, content and technological aspects (Chen & Jang, 2014; Chua & Jamil, 2014; Vaerenewyck, Shinas, & Steckel, 2017).

In particular, this quantitative research uses the TPACK model to organize and implement WALF in the field of mathematics through technological knowledge (HTML and PHP languages), content knowledge (formulas on the linear function and slope) and pedagogical knowledge (data simulation).

The research questions are:

- What is the impact of WALF on the assimilation of knowledge about the identification and evaluation of the linear function?
- What are the predictive models of the use of WALF in the field of mathematics education?

TPACK MODEL

TPACK is a model that proposes the use of technological, pedagogical and content knowledge to achieve an adequate integration of ICT in the teaching-learning process (Cejas-León, Navío-Gámez, & Barroso-Osuna, 2016; Chen & Jang, 2014; Gómez, 2015). Nowadays, this pedagogical and technological model is transforming school activities inside and outside the classroom (Bueno-Alastuey, Villarreal, & García-Esteban, 2018; Turgut, 2017). For example, the TPACK model facilitated the updating of activities for the educational process of mathematics through the use of Raptor software, YouTube videos and Facebook (Salas-Rueda, 2018).

The TPACK model is a framework of reference that allows the creation of active strategies for teaching and learning through the use of ICT (Chua & Jamil, 2014; Ozudogru & Ozudogru, 2019; Urban, Navarro, & Borron, 2018). Even the use of technological, content and pedagogical knowledge allows the creation of new virtual educational spaces (Brantley-Dias, & Ertmer, 2013; Oster-Levinz, & Klieger, 2010; Phillips, 2016).

The origins of the TPACK model come from the ideas about the use of pedagogical and content knowledge in the educational field proposed by Shulman (Leiva-Núñez, Ugalde-Meza, & Llorente-Cejudo, 2018). Subsequently, Mishra and Koehler created the TPACK model by integrating technological knowledge with content and pedagogical knowledge (Chua & Jamil, 2014).

Content Knowledge (CK) refers to the topics taught in the classes, Pedagogical Knowledge (PK) refers to teaching methods and Technological Knowledge (TK) refers to the use of ICT in the educational field (Brantley-Dias, & Ertmer, 2013; Cabero-Almenara, Roig-Vila, & Mengual-Andrés, 2017).

Also Pedagogical Content Knowledge (PCK) refers to what is used to teach the contents of the course, Technological Content Knowledge (TCK) refers to use of technology to transmit the contents of the course and Technological Pedagogical Knowledge (TPK) refers to use of technology in the educational context (Cabero-Almenara, Roig-Vila, & Mengual-Andrés, 2017; Gómez, 2015).

The TPACK model has been implemented in the courses on history (Vaerenewyck, Shinas, & Steckel, 2017), languages (Sancar-Tokmak & Yanpar-Yelken, 2015) and mathematics (Kartal & Cinar, 2018).

Kartal and Cinar (2018) used the TPACK model to analyze the impact of digital tools and technological applications (e.g., GeoGebra and Mathematica) in the teaching-learning process on mathematics. Even this pedagogical and technological model has improved academic performance through the creation of digital stories in language courses (Sancar-Tokmak & Yanpar-Yelken, 2015).

Finally, the TPACK model allows evaluating the use of digital tools and technological applications in the teaching-learning process and identifying the impact of ICT in school activities (Cabero-Almenara, Roig-Vila, & Mengual-Andrés, 2017; Cheng & Xie, 2018; Phillips, 2016).

METHOD

This quantitative research aims to analyze the design and implementation of WALF considering the TPACK model and data science.

Participants

The participants are 45 students, 19 men (42.22%) and 26 women (57.78%), who attended the Basic Math course (101 and 102 groups) in a Mexican university during the 2015 school year. These students attended the first semester of the Degrees in Administration (n=19, 42.22%), Commerce (n=13, 28.89%), Accounting (n=7, 15.56%) and Marketing (n=6, 13.33%).

Table 1. TPACK

No.	Knowledge	Description
1	Content Knowledge (CK)	Formulas on the linear function and slope
2	Pedagogical Knowledge (PK)	Data simulation
3	Technological Knowledge (TK)	HTML and PHP languages to build web applications
4	Technological Content Knowledge (TCK)	The web application presents the procedure to identify and evaluate the linear function. Step 1: Find the slope (m) Step 2: Find the ordinate at the origin (b) Step 3: Use the formula y = mx + b
5	Pedagogical Content Knowledge (PCK)	Data simulation presents the procedure for the identification and evaluation of the linear function
6	Technological Pedagogical Knowledge (TPK)	Students interact with the contents of the web application by means of data simulation
7	TPACK	Construction of WALF through technological pedagogical and content knowledge

Table 2. Description of WALF

No.	Element	Description
1	Case Name of use	WALF
2	Actor(s)	Student and WALF
3	Objective	WALF allows the identification and evaluation of the linear function by means of data simulation
4	Precondition	Students enter WALF through the Internet
5	Normal flow	1. The student provides coordinates 1 and 2 2. WALF presents the procedure and calculation of the slope 3. WALF presents the procedure and calculation of the ordinate at the origin 4. WALF presents the linear function (y = mx + b) 5. WALF evaluates the linear function (y = mx + b)
6	Postcondition	The student assimilates knowledge about the linear function by means of data simulation
7	Channel	Internet

Procedure

The procedure of this quantitative research began with the use of the TPACK model in the educational process on the linear function (See **Table 1**).

Table 2 describes the functions of WALF by means of the Use Cases Scenario.

WALF requests the information of the coordinates to start the simulation of data on the linear function (See **Figure 1**). This web application is available at the following web address: http://sistemasusables.com/mat/ap1/inicio.html

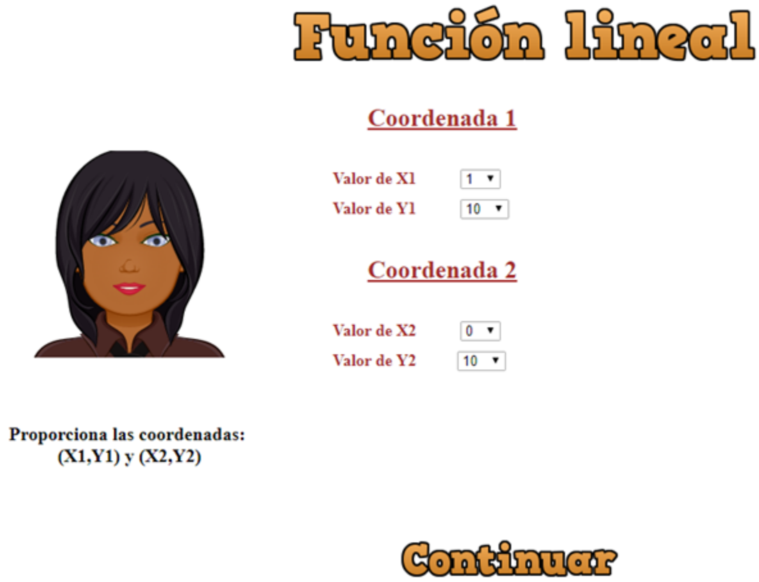

Figure 1. Home page of WALF

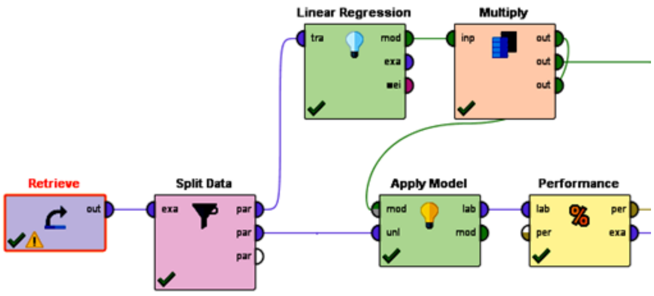

Figure 2. Calculation of machine learning

The research hypotheses about the use of WALF in the learning process are:

- Hypothesis 1 (H1): The contents of WALF positively influence the assimilation of knowledge on the identification of the linear function
- Hypothesis 2 (H2): The contents of WALF positively influence the assimilation of knowledge on the evaluation of the linear function

The predictive models on the use of WALF in the teaching-learning process of mathematics are:

- Predictive model 1: Contents of WALF and assimilation of knowledge on the identification of the linear function
- Predictive model 2: Contents of WALF and assimilation of knowledge on the evaluation of the linear function

Data Analysis

This quantitative research uses the Rapidminer tool to evaluate the hypotheses about the use of WALF in the educational field by means of machine learning (linear regression) with 50%, 60% and 70% of training (See **Figure 2**).

In addition, the Rapidminer tool allows the construction of predictive models on WALF and assimilation of knowledge through the decision tree technique (See **Figure 3**).

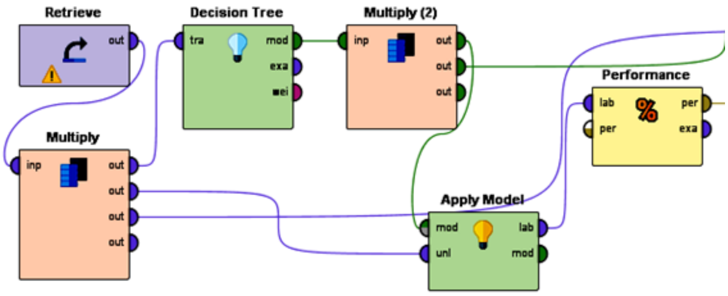

Figure 3. Construction of predictive models

Table 3. Questionnaire

Variable	Dimension	Question	Answer	n	%
Student	Career	1. What is your career?	Administration	19	42.22%
			Commerce	13	28.89%
			Accountancy	7	15.56%
			Marketing	6	13.33%
	Sex	2. Indicate your sex	Man	19	42.22%
			Woman	26	57.78%
	Age	3. What is your age?	18 years	21	46.67%
			19 years	20	44.44%
			20 years	2	4.44%
			21 years	1	2.22%
			22 years	1	2.22%
Educational process	Web Application	4. The contents of WALF facilitate the process of learning about mathematics	Too much (1)	31	68.89%
			Some (2)	13	28.89%
			Little (3)	1	2.22%
	Assimilation of knowledge	5. The use of technology in school activities facilitates the assimilation of knowledge on the identification of the linear function	Too much (1)	30	66.67%
			Some (2)	12	26.67%
			Little (3)	3	6.67%
		6. The use of technology in school activities facilitates the assimilation of knowledge on the evaluation of linear function	Too much (1)	25	55.56%
			Some (2)	17	37.78%
			Little (3)	3	6.67%

Data Collection

Data collection was done in a Mexican university at the end of the Functions unit during the 2015 school year. **Table 3** shows the measurement instrument (questionnaire).

RESULTS

Below are the results on the web interface and impact of WALF in the teaching-learning process on mathematics.

Web Interface

WALF is composed of 4 web pages:

- Web page 1: Request for information
- Web page 2: Calculation of the slope
- Web page 3: Calculation of the ordinate at the origin
- Web page 4: Identification and evaluation of the linear function (y = mx + b)

WALF requests the information on coordinates to start the data simulation on the linear function (See **Figure 4**).

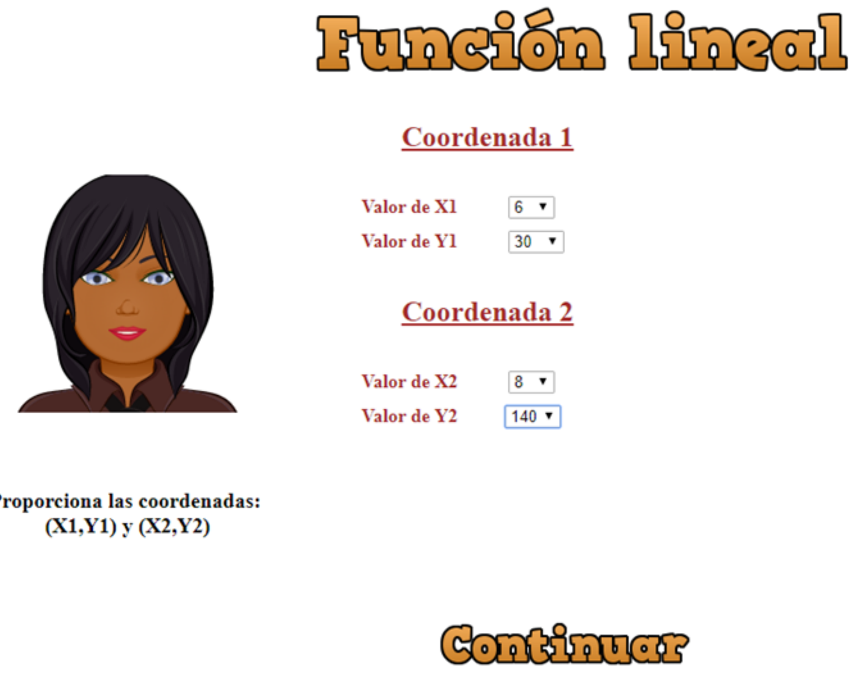

Figure 4. Web interface of WALF

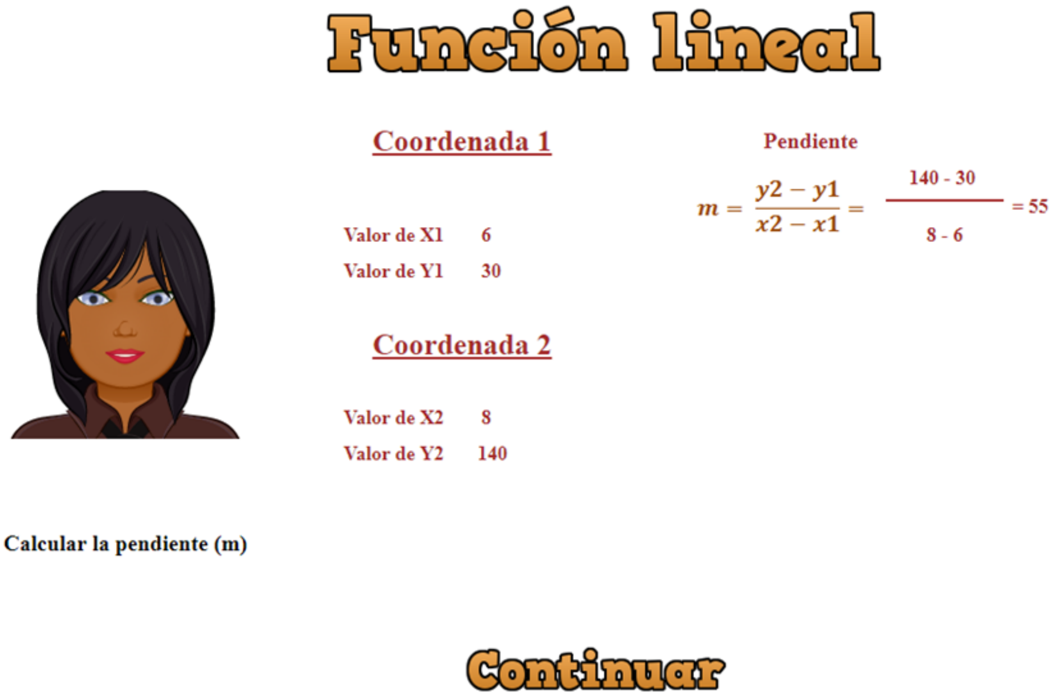

Figure 5. Calculation of the slope

WALF presents the formula and calculation of the slope (See **Figure 5**).

WALF presents the formula and calculation of the ordinate at the origin (See **Figure 6**).

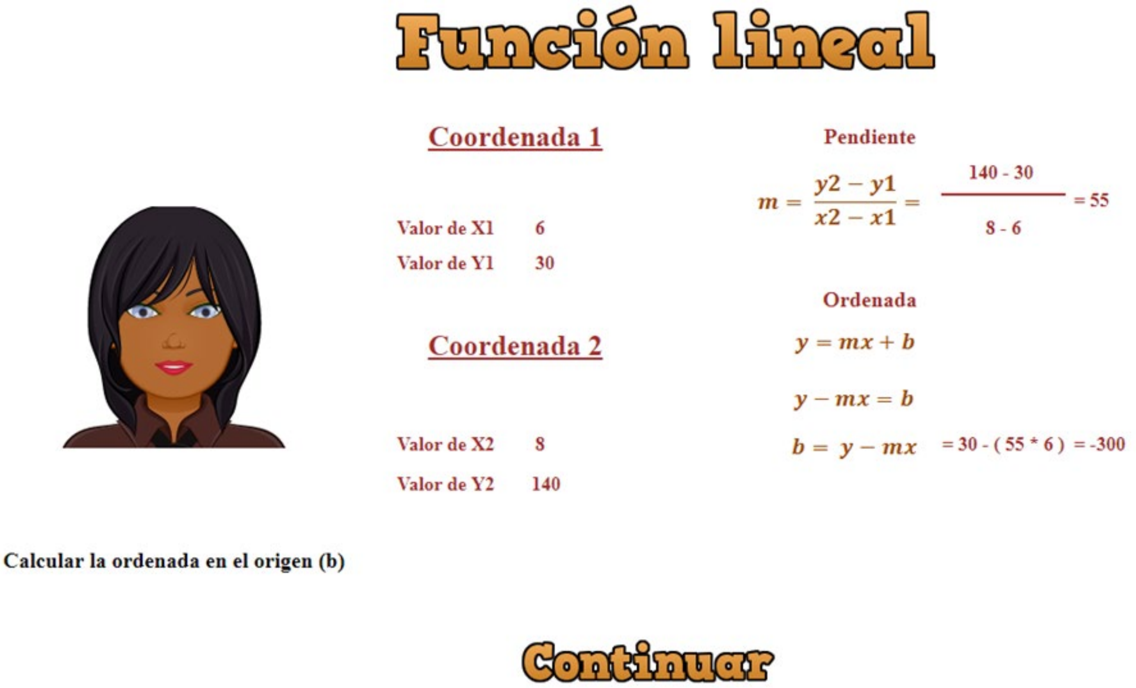

Figure 6. Calculation of the ordinate at the origin

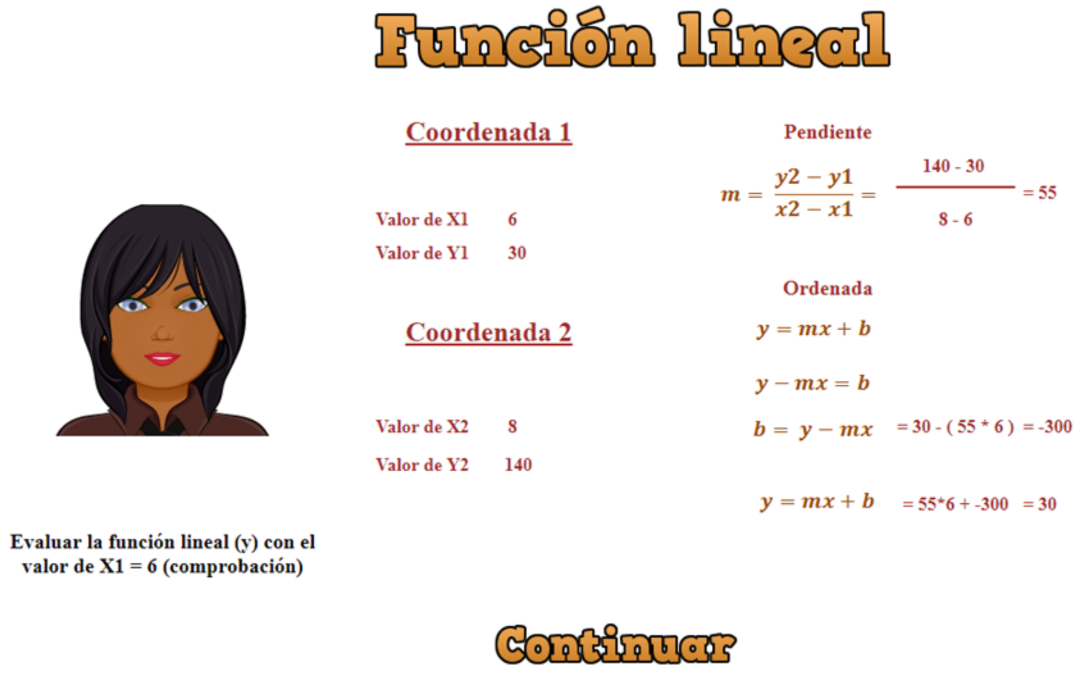

Figure 7. Identification and evaluation of the linear function

Finally, WALF presents and evaluates the linear function (See **Figure 7**).

Impact of WALF

Table 2 shows that the contents of WALF facilitate too much (n = 31, 68.89%), some (n = 13, 28.89%) and little (n = 1, 2.22%) the process of learning about mathematics. The use of technology in school activities facilitates too much (n = 30, 66.67%), some (n = 12, 26.67%) and little (n = 3, 6.67%) the assimilation of knowledge on the identification of the linear function. In the same way, the use of technology in school

Table 4. Results of machine learning

Hypothesis	Training	Linear regression	Conclusion	Error squared
H1: WALF → identification of the linear function	50%	y = 0.705x + 0.588	Accepted: 0.705	0.433
	60%	y = 0.749x + 0.500	Accepted: 0.749	0.514
	70%	y = 0.661x + 0.565	Accepted: 0.661	0.533
H2: WALF → evaluation of the linear function	50%	y = 0.656x + 0.519	Accepted: 0.656	0.427
	60%	y = 0.657x + 0.542	Accepted: 0.657	0.468
	70%	y = 0.578x + 0.661	Accepted: 0.578	0.668

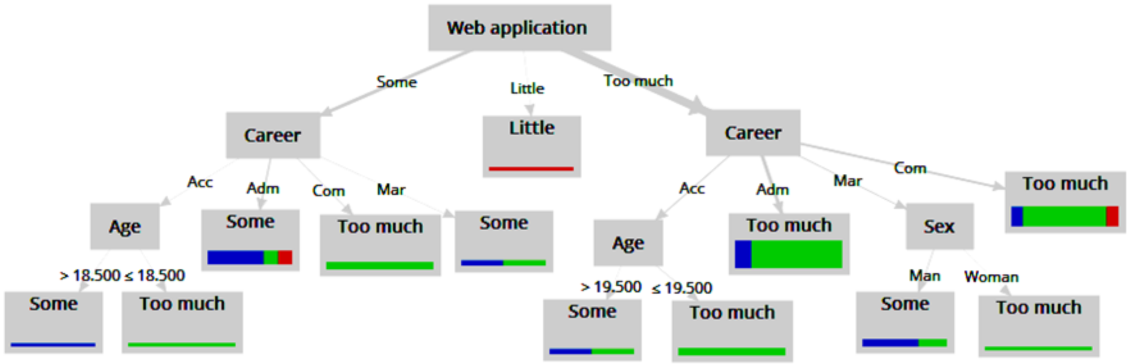

Figure 8. Predictive model 1 on the use of WALF

Table 5. Conditions in the predictive model 1

No.	WALF → learning process	Career	Sex	Age	Use of technology → assimilation of knowledge
1	Too much	Administration	-	-	Too much
2	Too much	Commerce	-	-	Too much
3	Too much	Accountancy	-	> 19.5 years	Some
4	Too much	Accountancy	-	≤ 19.5 years	Too much
5	Too much	Marketing	Man	-	Some
6	Too much	Marketing	Woman	-	Too much
7	Some	Administration	-	-	Some
8	Some	Commerce	-	-	Too much
9	Some	Accountancy	-	> 18.5 years	Some
10	Some	Accountancy	-	≤ 18.5 years	Too much
11	Some	Marketing	-	-	Some
12	Little	-	-	-	Little

activities facilitates too much (n = 25, 55.56%), some (n = 17, 37.78%) and little (n = 3, 6.67%) the assimilation of knowledge on evaluation of the linear function.

The results of machine learning with 50%, 60% and 70% of training indicate that the contents of WALF positively influence the assimilation of knowledge on the identification and evaluation of the linear function (See **Table 4**).

Identification of the Linear Function

The results of machine learning with 50% (0.705), 60% (0.749) and 70% (0.661) of training indicate that hypothesis 1 is accepted (See **Table 4**). Therefore, the contents of WALF positively influence the assimilation of knowledge on the identification of the linear function.

Figure 8 shows the predictive model 1 on the use of WALF. For example, if the student thinks that the contents of WALF facilitate too much the process of learning about mathematics, attends the career of Marketing and is Man then the use of technology in school activities facilitates some the assimilation of knowledge on the identification of the linear function.

Table 5 shows the 12 conditions of the predictive model 1 (accuracy of 80.00%). For example, if the student thinks that the contents of WALF facilitate some the process of learning about mathematics, attends the career

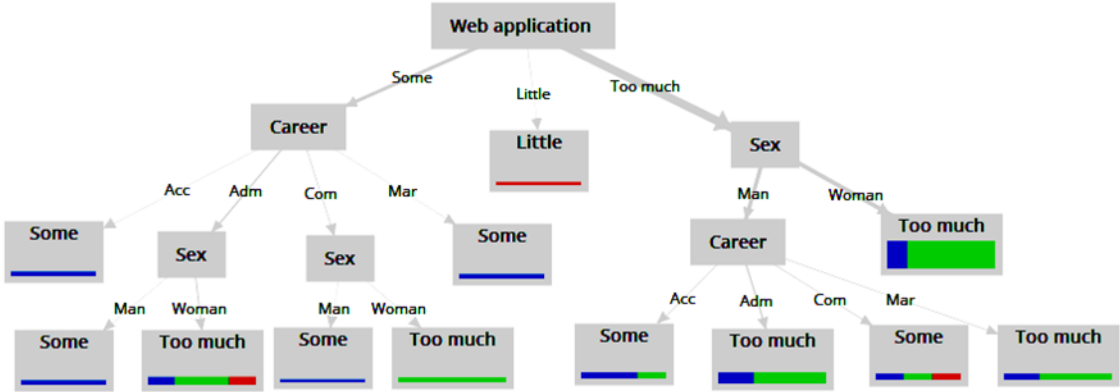

Figure 9. Predictive model 2 on the use of WALF

of Accounting and has an age > 18.5 years then the use of technology in school activities facilitates some the assimilation of knowledge on the identification of the linear function.

Table 5 presents 6 conditions where the use of technology in school activities facilitates too much the assimilation of knowledge on the identification of the linear function. For example, if the student thinks that the contents of WALF facilitate too much the process of learning about mathematics, attends the career of Marketing and is Woman then the use of technology in school activities facilitates too much the assimilation of knowledge on the identification of the linear function.

Likewise, the predictive model 1 has 5 conditions where the use of technology in school activities facilitates some the assimilation of knowledge on the identification of the linear function (See **Table 5**). For example, if the student thinks that the contents of WALF facilitate some the process of learning about mathematics and attends the career of Administration then the use of technology in school activities facilitates some the assimilation of knowledge on the identification of the linear function.

Finally, **Table 5** indicates 1 condition where the use of technology in school activities facilitates little the assimilation of knowledge on the identification of the linear function. For example, if the student thinks that the contents of WALF facilitate little the process of learning about mathematics then the use of technology in school activities facilitates little the assimilation of knowledge on the identification of the linear function.

Evaluation of Linear Function

The results of machine learning with 50% (0.656), 60% (0.657) and 70% (0.578) of training indicate that hypothesis 2 is accepted (See **Table 4**). Therefore, the contents of WALF positively influence the assimilation of knowledge on the evaluation of the linear function.

Figure 9 shows the predictive model 2 on the use of WALF. For example, if the student thinks that the contents of WALF facilitate too much the process of learning about mathematics, attends the career of Administration and is Man then the use of technology in school activities facilitates too much the assimilation of knowledge on the evaluation of linear function.

Table 6 shows 12 conditions of the predictive model 2 (accuracy of 75.56%). For example, if the student thinks that the contents of WALF facilitate some the process of learning about mathematics, attends the career of Commerce and is Woman then the use of technology in school activities facilitates too much the assimilation of knowledge on the evaluation of linear function.

Table 6. Conditions in the predictive model 2

No.	WALF → learning process	Career	Sex	Age	Use of technology → assimilation of knowledge
1	Too much	Administration	Man	-	Too much
2	Too much	Commerce	Man	-	Some
3	Too much	Accountancy	Man	-	Some
4	Too much	Marketing	Man	-	Too much
5	Too much	-	Woman	-	Too much
6	Some	Administration	Man	-	Some
7	Some	Administration	Woman	-	Too much
8	Some	Accountancy	-	-	Some
9	Some	Commerce	Man	-	Some
10	Some	Commerce	Woman	-	Too much
11	Some	Marketing	-	-	Some
12	Little	-	-	-	Little

Table 6 presents 5 conditions where the use of technology in school activities facilitates too much the assimilation of knowledge on the evaluation of linear function. For example, if the student thinks that the contents of WALF facilitate too much the process of learning about mathematics, attends the career of Administration and is Man then the use of technology in school activities facilitates too much the assimilation of knowledge on the evaluation of linear function.

Likewise, the predictive model 2 has 6 conditions where the use of technology in school activities facilitates some the assimilation of knowledge on the evaluation of linear function (See **Table 6**). For example, if the student thinks that the contents of WALF facilitate some the process of learning about mathematics and attends the career of Marketing then the use of technology in school activities facilitates some the assimilation of knowledge on the evaluation of linear function.

Finally, **Table 6** shows 1 condition where the use of technology in school activities facilitates little the assimilation of knowledge on the evaluation of linear function. For example, if the student thinks that the contents of WALF facilitate little the process of learning about mathematics then the use of technology in school activities facilitates little the assimilation of knowledge on the evaluation of linear function.

DISCUSSION

ICTs are causing teachers to design and carry out new school activities inside and outside the classroom (Cardellino, Araneda, & García, 2017; Earle & Fraser, 2017; Magen & Steinberger, 2017). In particular, this quantitative research analyzes the design and implementation of WALF considering the TPACK model and data science.

The TPACK model facilitated the construction of WALF through technological knowledge (HTML and PHP languages), content knowledge (formulas on the linear function and slope) and pedagogical knowledge (data simulation). The results of machine learning with 50%, 60% and 70% of training indicate that the contents of WALF positively influence the assimilation of knowledge about the identification and evaluation of the linear function.

This quantitative research shares the ideas of various authors (e.g., Martin, Ritzhaupt, Kumar, & Budhrani, 2019) about the use of technological tools in the educational field to develop competences in students.

Also, the decision tree technique (data science) identifies 2 predictive models on the use of WALF in the educational field and assimilation of knowledge with the accuracy greater than 75.50%. In the predictive model 1, if the student thinks that the contents of WALF facilitate too much the process of learning about mathematics, attends the career of Marketing and is Man then the use of technology in school activities facilitates some the assimilation of knowledge on the identification of the linear function. In the predictive model 2, if the student thinks that the contents of WALF facilitate too much the process of learning about mathematics, attends the career of Administration and is Man then the use of technology in school activities facilitates too much the assimilation of knowledge on the evaluation of linear function.

The TPACK model allows the transformation of teaching-learning conditions through technological, content and pedagogical knowledge (Bueno-Alastuey, Villarreal, & García-Esteban, 2018; Cheng & Xie, 2018, Urban, Navarro, & Borron, 2018). In particular, WALF and the TPACK model allow improving the learning process on mathematics through data simulation.

CONCLUSION

The TPACK model allows modifying the teaching-learning process through the incorporation of ICT in school activities. In particular, this research proposes the use of technological knowledge (HTML and PHP languages), content knowledge (formulas on the linear function and slope) and pedagogical knowledge (data simulation) for the construction of WALF.

The results of machine learning indicate that the contents of WALF positively influence the assimilation of knowledge about the identification and evaluation of the linear function. Also, data science identifies 2 predictive models on the use of WALF in the field of mathematics. WALF presents the procedure and calculation of the slope and the ordinate at the origin to facilitate the assimilation of knowledge on the identification and evaluation of the linear function.

The limitations of this quantitative research are related to the construction of WALF to present the simulation of the linear function and use of the Spanish language in the contents. Therefore, future investigations can create web applications for the educational process on the quadratic, exponential, rational and logarithmic functions by means of the TPACK model. Also, the contents can be designed considering the English language.

The implications of this research drive the use of the TPACK model in the educational field in order to improve teaching-learning conditions. Likewise, the design and construction of web applications allow innovating and updating school activities.

This research recommends the use of the TPACK model in the educational field in order to plan, organize and carry out school activities centered on students and create new virtual teaching-learning spaces. Likewise, the Rapidminer tool allows the calculation of machine learning and construction of predictive models. Finally, the TPACK model modifies the behavior and functions of students during the learning process through technological, content and pedagogical knowledge.

Disclosure statement

No potential conflict of interest was reported by the authors.

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