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ANÁLISE DE UM APLICATIVO WEB PARA APRENDIZAGEM DE MATEMÁTICA CONSIDERANDO ALGORITMOS DE APRENDIZAGEM DE MÁQUINA E TESTES NÃO PARAMÉTRICOS

ANALYSIS OF THE WEB APPLICATION FOR LEARNING MATHEMATICS CONSIDERING MACHINE LEARNING ALGORITHMS AND NON-PARAMETRIC TESTS

ANÁLISIS DE LA APLICACIÓN WEB PARA EL APRENDIZAJE DE LAS MATEMÁTICAS CONSIDERANDO ALGORITMOS DE APRENDIZAJE AUTOMÁTICO Y PRUEBAS NO PARAMÉTRICAS

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RESUMO

Introdução: Os professores de matemática podem mudar a forma de ensinar e aprender incorporando a tecnologia às atividades educacionais.
Objetivo: Analisar o uso do Aplicativo Web para Aprendizado de Matemática sobre Otimização com base na área de um retângulo por meio de Derivadas (WALOD), considerando algoritmos de aprendizado de máquina e testes não paramétricos. Esta ferramenta tecnológica apresenta o procedimento detalhado para calcular a área máxima de um retângulo utilizando um simulador web.
Métodos: Os 37 participantes são estudantes de Ciências da Terra que cursaram matemática durante o ano letivo de 2024. A amostra não é probabilística e as abordagens utilizadas são descritivas, causais e correlacionais.
Resultados: O teste de Mann-Whitney indica que o sexo do estudante influencia o uso do WALOD para a aprendizagem de matemática e a satisfação. Por outro lado, o teste de Kruskal-Wallis mostra que a idade dos estudantes influencia o uso do WALOD para a aprendizagem de matemática, a satisfação e a criação de espaços educacionais virtuais. Os resultados do algoritmo de regressão linear mostram que o uso do WALOD para o aprendizado de matemática influencia positivamente a motivação, a satisfação e a criação de um espaço educacional virtual. O algoritmo de árvore de decisão determinou três modelos preditivos para esta aplicação. No campo da matemática, as implicações práticas do uso do WALOD incluem o aprendizado personalizado, a facilidade de uso, a autonomia durante o processo de ensino e aprendizagem da matemática, e a possibilidade de tirar dúvidas a qualquer momento.
Conclusão: Concluindo, o WALOD é uma ferramenta inovadora e interativa que facilita o aprendizado da matemática sobre otimização por meio de derivadas, de qualquer lugar, e promove autonomia durante o processo educacional.

Palavras-chave: TIC; ensino; matemática; ensino superior; derivada

ABSTRACT

Introduction: Mathematics professors can change the way of teaching and learning by incorporating technology into educational activities.
Objective: To analyze the use of the Web Application for Learning mathematics about Optimization based on the area of a rectangle through Derivatives (WALOD), considering machine learning algorithms and non-parametric tests. This technological tool shows the detailed procedure to calculate the maximum area of a rectangle using a web simulator.
Methods: The 37 participants are students of Earth Sciences who took the course of Mathematics during the 2024 school year. The sample is non-probabilistic, and the scopes used are descriptive, causal, and correlational.
Results: The Mann-Whitney test indicates that students' sex influences the use of WALOD for learning mathematics and satisfaction. On the other hand, the Kruskal-Wallis test shows that age influences the use of WALOD for learning mathematics, satisfaction, and creation of virtual educational spaces. The results of the linear regression algorithm show that the use of WALOD for learning mathematics positively influences motivation, satisfaction, and the creation of virtual educational space. The decision tree algorithm determined three predictive models for this application. In the field of mathematics, the practical implications about the use of WALOD include personalized learning, ease of use, autonomy during the teaching and learning process of mathematics, and ability to resolve doubts at any time.
Conclusion: In conclusion, WALOD is an innovative and interactive tool that facilitates learning mathematics about optimization through derivatives from anywhere and fosters autonomy during the education process.

Keywords: ICT; teaching; mathematics; higher education; derivative

RESUMEN

Introducción: Los profesores de matemáticas pueden cambiar la forma de enseñar y aprender incorporando la tecnología a las actividades educativas.
Objetivo: Analizar el uso de la aplicación web para el aprendizaje de matemáticas sobre optimización basada en el área de un rectángulo mediante derivadas (WALOD) considerando los algoritmos de aprendizaje automático y pruebas no paramétricas. Esta herramienta tecnológica muestra el procedimiento detallado para calcular el área máxima de un rectángulo mediante un simulador web.
Métodos: Los 37 participantes son estudiantes de Ciencias de la Tierra que cursaron la asignatura de Matemáticas durante el año académico 2024. La muestra es no probabilística y los alcances utilizados son descriptivos, causales y correlacionales.
Resultados: La prueba de Mann-Whitney indica que el sexo del estudiante influye en el uso de WALOD para el aprendizaje de las matemáticas y la satisfacción. Por otro lado, la prueba de Kruskal-Wallis muestra que la edad influye en el uso de WALOD para el aprendizaje de las matemáticas, la satisfacción y la creación de espacios educativos virtuales. Los resultados del algoritmo de regresión lineal muestran que el uso de WALOD para el aprendizaje de las matemáticas influye positivamente en la motivación, la satisfacción y la creación de un espacio educativo virtual. El algoritmo de árbol de decisión determinó tres modelos predictivos para esta aplicación. En el ámbito de las matemáticas, las implicaciones prácticas del uso de WALOD incluyen el aprendizaje personalizado, la facilidad de uso, la autonomía durante el proceso de enseñanza-aprendizaje de las matemáticas y la posibilidad de resolver dudas en cualquier momento.
Conclusión: En conclusión, WALOD es una herramienta innovadora e interactiva que facilita el aprendizaje de las matemáticas sobre la optimización por medio de las derivadas desde cualquier lugar, y promueve la autonomía durante el proceso educativo.

Palabras clave: TIC; enseñanza; matemáticas; educación superior; derivada

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INTRODUCTION

Technological advances offer the advantage of learning without time and space restrictions (Muhammad et al., 2024; Niño-Rojas et al., 2024; Sari et al., 2025). According to Mailizar et al. (2025), Information and Communication Technology (ICT) represents an alternative for improving educational quality.

At the present time, digital tools have become a technological ally of the educational process because teachers can create accessible and useful virtual spaces (Duong et al., 2025; Hamadneh et al., 2024; Salas-Rueda, 2021). Furthermore, the incorporation of ICT has led to students becoming autonomous individuals with the ability to learn at any time (Niño-Rojas et al., 2024).

According to Duong et al. (2025), the future of education is strongly linked to technological advances found on the Internet. The benefits of web tools include personalized learning, autonomy, flexibility to learn from anywhere, peer communication, and active participation (Guzmán-González & Vesga-Bravo, 2024; Niño-Rojas et al., 2024).

Students learn at their own pace through web tools (De-la-Rosa, 2023; Karelkhan et al., 2023). For example, De-la-Rosa (2023) built a web application to reinforce knowledge of Mandarin Chinese through a digital dictionary, assessments, and lessons.

Digital tools also allow students to review topics (De-la-Rosa, 2023; Karelkhan et al., 2023). In fact, Wang (2022) implemented a web application on the topic of Finance considering the users' prior knowledge. Furthermore, the ArcGIS application enabled the creation of spatial maps online, which promotes reflection on geography topics (Karelkhan et al., 2023).

Data science allows the identification of information hidden through machine learning algorithms such as linear regression and decision trees. In fact, these algorithms establish new relationships between independent and dependent variables, which are used to predict events in any area of knowledge (Bekturova et al., 2025; Cinar et al., 2025; Doleck et al., 2025; Salas-Rueda et al., 2020). For example, Salas-Rueda (2021) used the linear regression algorithm with 60%, 70%, and 80% of the sample training section, to analyze the incorporation of Facebook into the mathematics teaching-learning process, considering a sample of 46 students. Similarly, this machine learning algorithm was used to evaluate the use of technology in the assimilation of knowledge and development of web programming skills considering a sample of 28 students (Salas-Rueda, 2020). Similarly, the decision tree algorithm was used to build predictive models on the use of Moodle and the teachers' profiles (Salas-Rueda et al., 2020).

The professor of the mathematics course decided to develop the Web Application for Learning about Optimization through Derivatives (WALOD) using the PHP programming language. This technological tool shows the detailed procedure for calculating the maximum area of a rectangle using a web simulator. In this research, linear regression and decision tree algorithms were used to establish forecasting models related to motivation, satisfaction, and the creation of educational virtual spaces. The aim of this mixed research is to analyze the use of WALOD in the Mathematics course considering machine learning algorithms and non-parametric tests. The research questions are:

- How does the use of WALOD for learning mathematics influence motivation, satisfaction, and the creation of virtual educational spaces, considering the linear regression algorithm?
- How does the sex of the students influence the use of WALOD for learning mathematics, motivation, satisfaction, and the creation of virtual educational spaces, considering the Mann-Whitney test?
- How does the age of the students influence the use of WALOD for learning mathematics, motivation, satisfaction, and the creation of virtual educational spaces, considering the Kruskal-Wallis test?
- What are the predictive models for WALOD considering the decision tree algorithm?
- What is the students' perception about the use of WALOD in the Mathematics course?

1. LITERATURE REVIEW

In mathematics courses, technological tools such as web applications help students to understand topics and develop their skills (Bueno et al., 2023; Rocha et al., 2020; Ticse et al., 2023). For example, Bueno et al. (2023) used GeoGebra to explain topics related to functions through graphs and animations.

Rocha et al. (2020) used the platform called MyMathLab to share resources and content about functions. In fact, the students of the mathematics course accessed this tool to consult the digital textbook and take online exams using mobile devices (Rocha et al., 2020).

According to Niño-Rojas et al. (2024), the use of adaptive educational systems in mathematics courses allows personalized learning, reinforcement of knowledge, problem solving, participation, active role, collaborative work, and skills development. In fact, these systems facilitated learning about algebra, geometry, and the fundamentals of mathematics (Niño-Rojas et al., 2024).

In a secondary school in Chile, the educator incorporated GeoGebra to facilitate learning about Calculus topics (Ticse et al., 2023). In particular, this tool allowed them to graph velocity functions considering the slope of the tangent line (Ticse et al., 2023).

Fan et al. (2021) point out that online educational platforms are highly relevant in the field of mathematics education. Consequently, Fan et al. (2021) developed an educational platform that personalizes mathematics content linked to digital presentations, multimedia resources, and activities considering students' profiles.

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During the COVID-19 pandemic, mathematics professors used videoconferencing systems such as Zoom and Google Meet to teach classes remotely, answer questions, and exchange ideas with students (Sengil-Akar & Kurtoglu-Erden, 2021). These teachers also used WhatsApp as a means of communication and educational platforms to send the information of the courses (Sengil-Akar & Kurtoglu-Erden, 2021).
Finally, educators have innovated mathematics courses through various tools such as GeoGebra to graph functions (Bueno et al., 2023; Ticse et al., 2023), MyMathLab to access school content from mobile phones (Rocha et al., 2020), video conferencing systems to teach courses remotely (Sengil-Akar & Kurtoglu-Erden, 2021) and online educational platforms to consult resources (Fan et al., 2021).

2. METHODS

The specific objectives of this mixed research are (1) to analyze the use of WALOD for motivation, satisfaction and creation of virtual educational space through the linear regression algorithm, (2) to analyze the impact of the students' sex in the use of WALOD for learning mathematics, motivation, satisfaction, and the creation of virtual educational spaces considering the Mann-Whitney test, (3) to analyze the impact of the students' age in the use of WALOD for learning mathematics, motivation, satisfaction, and the creation of virtual educational spaces considering Kruskal-Wallis test, (4) to create models on WALOD through the decision tree algorithm and (5) to analyze the students' perception of the use of this application.

2.1 Sample

The participants are 37 students of Earth Sciences who took the course of Mathematics during the 2024 school year. The sample is non-probabilistic, and the scopes used are descriptive, causal, and correlational.
WALOD was built using the PHP programming language to facilitate learning mathematics through derivatives. Specifically, it shows the detailed procedure to calculate the maximum area of a rectangle using a web simulator. WALOD is a technological tool that enables personalized learning about optimization based on the area of a rectangle through derivatives (see Figure 1). The students learn step-by-step how to solve the problem of the maximum area of a rectangle considering the presentation of the formula for the perimeter (step 1), the resolution of the variable y (step 2), the substitution in the formula for the area (step 3), the use of the derivative (step 4), the procedure to find the value of the base (step 5), the identification of the value of the height (step 6), and the calculation of the maximum area of the rectangle (step 7).
The web simulator of WALOD presents the step-by-step procedure about the use of derivatives to calculate the maximum area of the rectangle. In the classroom, the mathematics instructor explained several exercises related to the use of derivatives. The students could access WALOD via mobile devices during the face-to-face sessions. After the classes, these students used WALOD to review the topics and complete the assignments for the Derivatives Unit. The independent variable is the use of WALOD for learning mathematics through derivatives. The dependent variables are Motivation, Satisfaction, and the creation of a virtual educational space. The hypotheses of this study are:

- Hypothesis 1: The use of WALOD for learning mathematics positively influences motivation
- Hypothesis 2: The use of WALOD for learning mathematics positively influences satisfaction
- Hypothesis 3: The use of WALOD for learning mathematics positively influences the creation of virtual educational space

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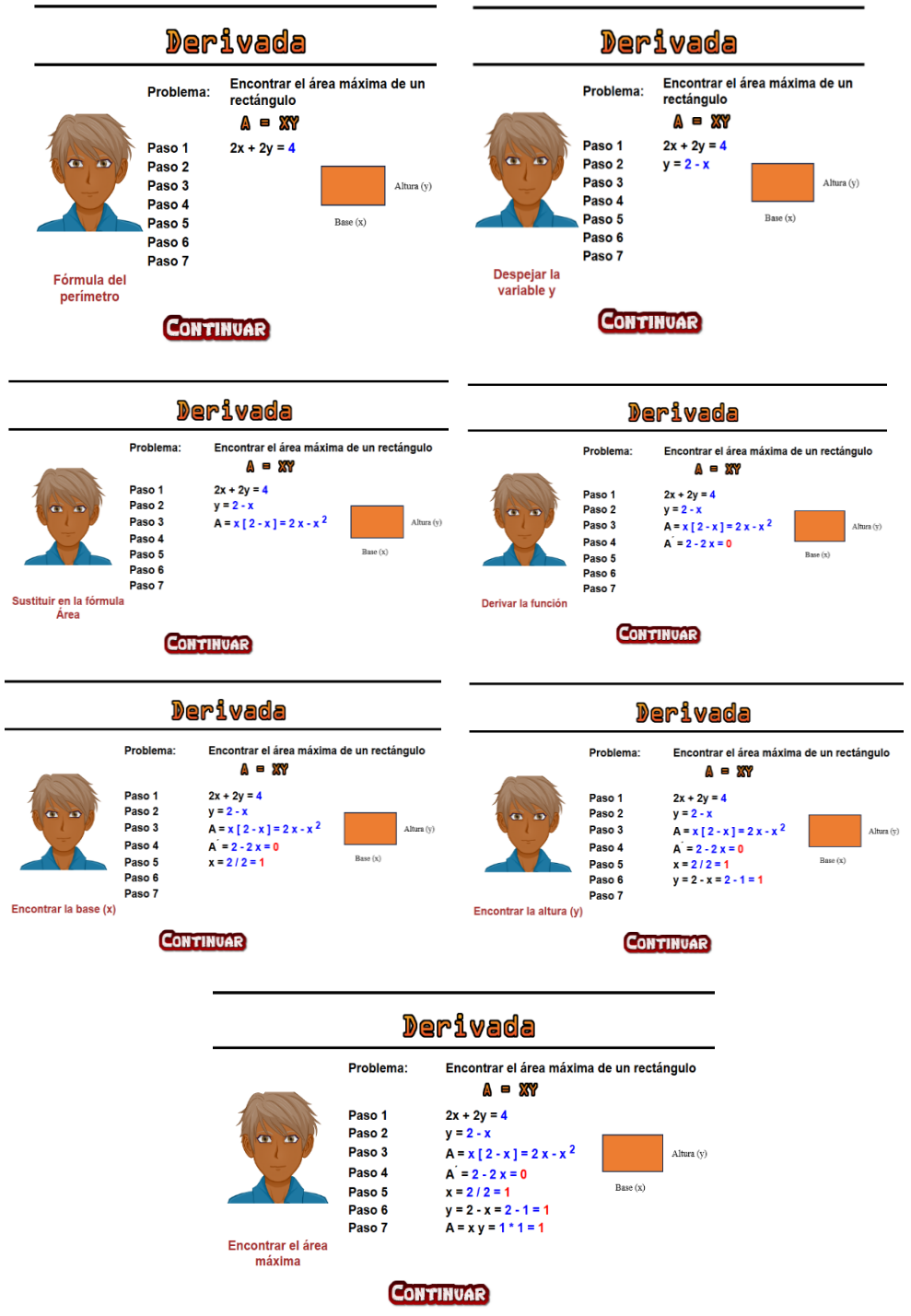


Figure 1 - Simulator of WALOD

On the other hand, the models obtained from the decision tree algorithm are:

- Model 1 on WALOD, motivation, and student profile
- Model 2 on WALOD, student satisfaction, and student profile
- Model 3 on WALOD, the creation of virtual educational space, and student profile

This study used the non-parametric test known as Mann-Whitney to determine whether the sex of the students influences use, motivation, satisfaction, and the creation of virtual educational spaces when considering this technological tool. Therefore, the hypotheses are:

- Null hypothesis 1: $\mu 1 = \mu 2$. The student's sex, man or woman, does not influence the use of WALOD for learning mathematics

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- Null hypothesis 2: $\mu1 = \mu2$. The student's sex, man or woman, does not influence motivation through WALOD
- Null hypothesis 3: $\mu1 = \mu2$. The student's sex, man or woman, does not influence satisfaction through WALOD
- Null hypothesis 4: $\mu1 = \mu2$. The student's sex, man or woman, does not influence the creation of virtual educational spaces through WALOD

Kruskal-Wallis test determined whether the age of the students influences use, motivation, satisfaction, and the creation of virtual educational spaces considering this technological tool. Therefore, the hypotheses are:

- Null hypothesis 1: $\mu1 = \mu2 = \mu3$. The student's age (18 years, 19 years, and > 19 years) does not influence the use of WALOD for learning mathematics
- Null hypothesis 2: $\mu1 = \mu2 = \mu3$. The students' age (18 years, 19 years, and > 19 years) does not influence motivation through WALOD
- Null hypothesis 3: $\mu1 = \mu2 = \mu3$. The students' age (18 years, 19 years, and > 19 years) does not influence satisfaction through WALOD
- Null hypothesis 4: $\mu1 = \mu2 = \mu3$. The students' age (18 years, 19 years, and > 19 years) does not influence the creation of virtual educational spaces through WALOD

2.2 Data collection instruments

Data was collected through a digital questionnaire in the Mathematics course during the 2024-1 academic year (See Table 1). This measurement instrument consists of 4 closed-ended questions about the use of WALOD, 2 closed-ended questions about the student profile, and 2 open-ended questions about the perceptions.

Table 1 - Questionnaire on WALOD

Variable	Dimension	Question	Answer	n	%
WALOD	Use	1. The use of WALOD facilitates learning mathematics about the maximum area of a rectangle through derivatives	Very much (1)	17	45.95%
			Much (2)	20	54.05%
			Little (3)	0	0.00%
			Very little (4)	0	0.00%
	Motivation	2. WALOD increases motivation	Very much (1)	11	29.73%
			Much (2)	22	59.46%
			Little (3)	4	10.81%
			Very little (4)	0	0.00%
	Satisfaction	3. WALOD increases satisfaction	Very much (1)	15	40.54%
			Much (2)	20	54.05%
			Little (3)	2	5.41%
			Very little (4)	0	0.00%
	Virtual educational spaces	4. WALOD facilitates the creation of virtual educational spaces	Very much (1)	16	43.24%
			Much (2)	19	51.35%
			Little (3)	2	5.41%
			Very little (4)	0	0.00%
Student	Sáb	5. Indicate your sex	Man	16	43.24%
			Woman	21	56.76%
	Age	6. Indicate your age	18 years	16	43.24%
			19 years	13	35.14%
			> 19 years	8	21.62%
Perception	Benefits of WALOD	7. Indicate the benefits of WALOD	Open	-	-
	Distance education	8. Does WALOD promote distance education?	Open	-	-

Table 2 presents the criteria on Load Factor, Cronbach's Alpha, and Composite Reliability to validate the questionnaire on the use of WALOD.

Table 2 - Validation criteria for the questionnaire

Variable	Dimension	Load Factor	Cronbach's Alpha	Composite Reliability
WALOD	Use	0.837	0.794	0.869
	Motivation	0.765		
	Satisfaction	0.668		
	Virtual educational spaces	0.884		

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2.3 Statistical analysis

For data analysis, the RapidMiner tool was used to calculate linear regression and decision tree algorithms. In the linear regression algorithm, the training section with 40%, 50%, and 60% of the sample allowed the evaluation of hypotheses considering the use of WALOD, and the evaluation section with 60%, 50%, and 40% of the sample allowed the identification of the function for predicting educational phenomena through the squared error.

In the decision tree algorithm, the target variables are Motivation, Satisfaction, and Creation of virtual educational spaces. It is worth noting that sex and age are criteria used during the construction of these predictive models.

To find the most meaningful words in relation to the open-ended questions, this study used the Word Cloud application. The questions analyzed about the use of WALOD were: (1) Indicate the benefits of the web application, and (2) Does the web application promote distance education? The variables used in open question 1 on benefits are an easy-to-use application, review of the topics, personalized learning, a support tool, flexibility, and an interactive application. In addition, the variables used in open question 2 on distance education are access, learning mathematics, online learning, and a useful tool.

3. RESULTS

The use of WALOD facilitates very much (n = 17, 45.95%) and much (n = 20, 54.05%) learning mathematics about the maximum area of a rectangle through derivatives. Table 3 shows the results of the non-parametric test known as Mann-Whitney. This test is used to determine whether the sex of the students influences use, motivation, satisfaction, and the creation of virtual educational spaces considering this technological tool.

Table 3 - Mann-Whitney test

Variable	Hypothesis	Description	Significance level (α)	Z	Result	Conclusion
Use	Null hypothesis 1: μ1 = μ2	The student's sex, man or woman, does not influence the use of WALOD for learning mathematics	0.15 ± 1.44	-1.655	Rejected	The student's sex influences the use of WALOD for learning mathematics
			0.10 ± 1.64	-1.655	Rejected	The student's sex influences the use of WALOD for learning mathematics
Motivation	Null hypothesis 2: μ1 = μ2	The student's sex, man or woman, does not influence motivation through WALOD	0.15 ± 1.44	-1.103	Accepted	The student's sex does not influence motivation through WALOD
			0.10 ± 1.64	-1.103	Accepted	The student's sex does not influence motivation through WALOD
Satisfaction	Null hypothesis 3: μ1 = μ2	The student's sex, man or woman, does not influence satisfaction through WALOD	0.15 ± 1.44	-2.575	Rejected	The student's sex influences satisfaction through WALOD
			0.10 ± 1.64	-2.575	Rejected	The student's sex influences satisfaction through WALOD
Virtual educational spaces	Null hypothesis 4: μ1 = μ2	The student's sex, man or woman, does not influence the creation of virtual educational spaces through WALOD	0.15 ± 1.44	-0.490	Accepted	The student's sex does not influence the creation of virtual educational spaces through WALOD
			0.10 ± 1.64	-0.490	Accepted	The student's sex does not influence the creation of virtual educational spaces through WALOD

Table 4 shows the results of the non-parametric test known as Kruskal-Wallis. This test is used to determine whether the age of the students influences use, motivation, satisfaction, and the creation of virtual educational spaces considering this technological tool.

Table 4 - Kruskal-Wallis test

Variable	Hypothesis	Description	Significance level (α)	K	Result	Conclusion
Use	Null hypothesis 1: μ1 = μ2 = μ3	The student's age, 18 years, 19 years and > 19 years, does not influence the use of WALOD for learning mathematics	0.10 Value: 4.605	5.720	Rejected	The student's age influences the use of WALOD for learning mathematics
Motivation	Null hypothesis 2: μ1 = μ2 = μ3	The student's age, 18 years, 19 years and > 19 years, does not influence motivation through WALOD	0.10 Value: 4.605	3.5866	Accepted	The student's age does not influence motivation through WALOD
Satisfaction	Null hypothesis 3: μ1 = μ2 = μ3	The student's age, 18 years, 19 years and > 19 years, does not influence satisfaction through WALOD	0.10 Value: 4.605	19.102	Rejected	The student's age influences satisfaction through WALOD
Virtual educational spaces	Null hypothesis 4: μ1 = μ2 = μ3	The student's age, 18 years, 19 years and > 19 years, does not influence the creation of virtual educational spaces through WALOD	0.10 Value: 4.605	5.6389	Rejected	The student's age influences the creation of virtual educational spaces through WALOD

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The results of linear regression indicate that the use of WALOD for learning mathematics through derivatives positively influences motivation, satisfaction, and the creation of virtual educational space (See Table 5).

Table 5 - Results of linear regression

Hypothesis	Sample	Model	Value of p	Conclusion	Squared error
H1	40%	y = 0.666x + 0.666	p < 0.050	Accepted	0.328
	50%	y = 0.715x + 0.659	p < 0.050	Accepted	0.300
	60%	y = 0.743x + 0.589	p < 0.050	Accepted	0.362
H2	40%	y = 0.499x + 0.666	p < 0.050	Accepted	0.432
	50%	y = 0.466x + 0.733	p < 0.050	Accepted	0.383
	60%	y = 0.401x + 1.042	p < 0.050	Accepted	0.184
H3	40%	y = 0.611x + 0.555	p < 0.050	Accepted	0.230
	50%	y = 0.568x + 0.681	p < 0.050	Accepted	0.227
	60%	y = 0.700x + 0.521	p < 0.050	Accepted	0.142

Table 6 shows that the values of Pearson correlation are Use-Motivation (0.51593983), Use-Satisfaction (0.376762694), Use-Virtual educational spaces (0.700437911), Motivation-Satisfaction (0.34822112), Motivation-Virtual educational spaces (0.557756598) and Satisfaction-Virtual educational spaces (0.483898943).

Table 6 - Pearson correlation

	Use	Motivation	Satisfaction	Virtual educational spaces
Use	1	0.51593983	0.376762694	0.700437911
Motivation	0.51593983	1	0.34822112	0.557756598
Satisfaction	0.376762694	0.34822112	1	0.483898943
Virtual educational spaces	0.700437911	0.557756598	0.483898943	1

3.1 Motivation

WALOD increases very much (n = 11, 29.73%), much (n = 22, 59.46%), and little (n = 4, 10.81%) motivation. The results with 40% (0.666), 50% (0.715), and 60% (0.743) of the sample indicate that the use of WALOD for learning mathematics positively influences motivation. Likewise, the function y = 0.715x + 0.659 has the smallest squared error at 0.300; therefore, this linear model allows us to predict motivation.

Table 7 shows 10 conditions of the model on WALOD and motivation with an accuracy of 75.68%. For example, if the student considers that the use of WALOD facilitates very much learning mathematics about the maximum area of a rectangle through derivatives very much and is 19 years old then this application increases much motivation.

The age-determined 10 conditions to predict motivation. For example, if the student considers that the use of WALOD facilitates learning mathematics about the maximum area of a rectangle through derivatives, is male, and is 18 years old, then this application increases motivation very much. In addition, the sex determined 8 conditions about WALOD. For example, if the student considers that the use of WALOD facilitates learning mathematics about the maximum area of a rectangle through derivatives, is a man, and is 19 years old, then this application increases motivation.

3.2 Satisfaction

WALOD increases very much (n = 15, 40.54%), much (n = 20, 54.05%), and little (n = 2, 5.41%) satisfaction. The results with 40% (0.499), 50% (0.466), and 60% (0.401) of the sample indicate that the use of WALOD for learning mathematics positively influences satisfaction. Furthermore, the function y = 0.401x + 1.042 has the smallest squared error at 0.184; therefore, this linear model allows to predict satisfaction.

Table 7 shows 9 conditions about WALOD and satisfaction with an accuracy of 75.68%. For example, if the student considers that the use of WALOD facilitates learning mathematics about the maximum area of a rectangle through derivatives, has 18 years old and is a man, then this application increases satisfaction.

The age determined 10 conditions to predict satisfaction. For example, if the student considers that the use of WALOD facilitates learning mathematics about the maximum area of a rectangle through derivatives and has 19 years old then this application increases much satisfaction. In addition, the sex determined 6 conditions about WALOD. For example, if a student considers that the use of WALOD facilitates much learning mathematics about the maximum area of a rectangle through derivatives, is a woman and has 19 years old, then this application increases much satisfaction.

3.3 Creation of virtual educational spaces

WALOD facilitates very much (n = 16, 43.24%), much (n = 19, 51.35%), and little (n = 2, 5.41%) the creation of virtual educational spaces. The results with 40% (0.611), 50% (0.568), and 60% (0.700) of the sample indicate that the use of WALOD for learning mathematics positively influences the creation of virtual educational space. The function y = 0.700x + 0.521 has the smallest squared error at 0.142, therefore, this linear model allows to predict the creation of virtual educational spaces.

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Table 7 shows 11 conditions about WALOD and the creation of virtual educational spaces with an accuracy of 83.78%. For example, if the student considers that the use of WALOD facilitates very much learning mathematics about the maximum area of a rectangle through derivatives, has 18 years old and is a man then this application facilitates very much the creation of virtual educational spaces.
The age determined 11 conditions to predict the creation of virtual educational spaces. For example, if the student considers that the use of WALOD facilitates much learning mathematics about the maximum area of a rectangle through derivatives, has 19 years old and is a man then this application facilitates very much the creation of virtual educational spaces. In addition, the sex determined 10 conditions about WALOD. For example, if a student considers that the use of WALOD facilitates much learning mathematics about the maximum area of a rectangle through derivatives, has 18 years old and is a woman then this application facilitates very much the creation of virtual educational spaces.

Table 7 - Models on motivation, satisfaction and virtual educational spaces

Model on WALOD and motivation				
No.	WALOD → learning mathematics	Sex	Age	WALOD → motivation
1	Very much	Man	18	Very much
2	Very much	Woman	18	Much
3	Very much	-	19	Much
4	Very much	Man	> 19	Very much
5	Very much	Woman	> 19	Very much
6	Much	Man	> 19	Much
7	Much	Woman	> 19	Very much
8	Much	-	18	Much
9	Much	Man	19	Much
10	Much	Woman	19	Very much
Model on WALOD and satisfaction				
No.	WALOD → learning mathematics	Sex	Age	WALOD → satisfaction
1	Very much	Man	> 19	Very much
2	Very much	Woman	> 19	Little
3	Very much	-	19	Much
4	Very much	-	18	Very much
5	Much	-	> 19	Much
6	Much	Man	19	Very much
7	Much	Woman	19	Much
8	Much	Man	18	Much
9	Much	Woman	18	Much
Model on WALOD and virtual educational spaces				
No.	WALOD → learning mathematics	Sex	Age	WALOD → virtual educational spaces
1	Very much	Man	> 19	Very much
2	Very much	Woman	> 19	Much
3	Very much	-	19	Very much
4	Very much	Man	18	Very much
5	Very much	Woman	18	Much
6	Much	Man	> 19	Much
7	Much	Woman	> 19	Very much
8	Much	Man	19	Very much
9	Much	Woman	19	Very much
10	Much	Man	18	Much
11	Much	Woman	18	Very much

3.4 Benefits

According to the students of the Mathematics course, WALOD is an easy-to-use application and allowed learning about real-life problems such as the maximum area of a rectangle.
“Because it's easy to understand and use, there's a greater chance of understanding the topic”
“I can use the application at any time. It is a very easy-to-use tool”
Furthermore, the students reviewed the topics covered in the classes and practiced mathematical procedures through WALOD.
“It facilitates the understanding of the topics covered in class”
“With its help, I review and practice the procedures”
The students of Earth Sciences mention that WALOD facilitated personalized learning.
“I have individualized learning and it facilitates access”
“It’s benefit is the help to better understand the topics”
WALOD is a support tool for the teaching and learning process of mathematics through a web simulator.

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“Having a tool that helps with better understanding”
“It facilitates the comprehension of topics in a more practical way”
Furthermore, WALOD offered flexibility in terms of time and location during the educational process about the use of derivatives to maximize the area of a rectangle.
“The educational app has made learning easy and accessible for people anywhere, with the goal of being engaging and understandable”
“It's accessible from anywhere, and it's also free”
Finally, the students of the Mathematics course consider WALOD to be an innovative and interactive application for the field of mathematics.
“Learning on the web simulator is innovative and adapted for new generations. Furthermore, it is a website that is easy for anyone to use”
“The visualization of topics covered in the classes and the interactive review format facilitate access and completion of assignments remotely”
Regarding the open question “Indicate the benefits of WALOD”, the most significant words are help (n = 15), learning (n = 8), application (n = 6), facilitates (n = 5), easy (n = 5), topic (n = 5), class (n = 4), understand (n = 4), accessible (n = 3), access (n = 3), exercises (n = 3), understanding (n = 3) and students (n = 3).

3.5 Distance Learning

The students of Earth Sciences expressed that WALOD facilitated distance learning in the Mathematics course.
“Yes, thanks to it. I was able to better visualize the procedure of the problem, and it is useful for resolving doubts”
“Yes, it helps understanding the topics because the numbering of steps and color differentiation. It allows me to follow the process to reach the solution without getting lost”
According to the respondents, mobile devices allow access to WALOD for learning mathematics through derivatives from anywhere.
“Yes, firstly because it adapts to any device and secondly because it’s easy to interact with the platform”
“Yes, because it lets me learn from anywhere”
In this research, WALOD also facilitated distance learning due to its easy access from any device.
“Yes, because it can be easily accessed from any device at any time of day”
“Yes, because it is easy to use. It can be opened on any device with an internet connection, and can be viewed anywhere and anytime”
In addition, WALOD facilitated online learning about derivatives because this tool is available during 365 days of year.
“Yes, because it is accessible at all times”
“Yes, because I can learn at my own pace”
Finally, the students of the Mathematics course point out that WALOD is useful for distance learning.
“Yes, since it can be used anytime and anywhere. Therefore, it is a very useful tool for distance learning”
“It definitely facilitates education and offers us a convenient and quick way to study without having to depend on someone”
For the open question “Does WALOD promote distance education?”, the most significant words are place (n = 8), help (n = 7), device (n = 6), learning (n = 5), internet (n = 5), learn (n = 4), exercises (n = 4), procedure (n = 4), perform (n = 4), see (n = 4), access (n = 3), doubts (n = 3), facilitates (n = 3), easy (n = 3) and time (n = 3).

4. DISCUSSION

Sari et al. (2025) explain that technology is a means capable of eliminating the barriers of time and space during learning. According to the students of the Mathematics course, WALOD is an easy-to-use application that helped the review of topics covered in the classroom.
As Bueno et al. (2023) mention, web applications help to understand mathematical concepts at any time. In this study, 100% of the participants felt that the use of WALOD facilitates very much and much learning mathematics about the maximum area of a rectangle through derivatives. At significance levels of $\alpha = 0.15$ and $\alpha = 0.10$, the Mann-Whitney test indicates that the student's sex influences the use of WALOD for learning mathematics. On the other hand, the Kruskal-Wallis test shows that the age of the participants influences the use of WALOD for learning mathematics.
Niño-Rojas et al. (2024) highlight that web tools offer the advantage of increasing participants' autonomy during the educational process. About the open question “Indicate the benefits of WALOD”, the students of Earth Sciences emphasized the words “help” and “learning” because WALOD allows that the users control the learning process through the web simulator.
Educational quality can be improved through the efficient integration of ICT in schools (Jaya, 2026; Kesim, 2026; Mailizar et al., 2025; Salas-Rueda, 2020). Furthermore, the results of the question “Does WALOD promote distance education?” indicate that the

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most significant words are “place” and “help” because the students of the Mathematics course use WALOD at any time regardless of physical location.

4.1 Motivation

Rocha et al. (2020) explain that students use mobile devices to learn mathematics through web applications. The students of Earth Sciences express that WALOD facilitated the learning process about the maximum area of a rectangle through derivatives from anywhere.

Online tools allow that teachers create accessible and useful learning environments (Duong et al., 2025; Hamadneh et al., 2024; Ticse et al., 2023). In this research, 89.19% of respondents believe that WALOD increases very much and much motivation. At significance levels of $\alpha = 0.15$ and $\alpha = 0.10$, the Mann-Whitney test indicates that the student's sex does not influence motivation through WALOD. On the other hand, the Kruskal-Wallis test shows that the age of the participants does not influence motivation.

Mathematics teachers use ICT to improve knowledge assimilation and skills development (Bueno et al., 2023; Rocha et al., 2020; Ticse et al., 2023). According to participants, WALOD is a support tool for the teaching and learning process related to the calculation of the maximum area of a rectangle.

The results of the linear regression algorithm show that the use of WALOD for learning mathematics positively influences motivation. Furthermore, the function, $y = 0.715x + 0.659$, allows the prediction of this technological and educational phenomenon. The decision tree algorithm established that sex and age influence motivation through WALOD. Finally, the correlation between the use of WALOD for learning mathematics through derivatives and motivation is 0.516.

4.2 Satisfaction

Ticse et al. (2023) and Bueno et al. (2023) indicate that the incorporation of web applications positively impacts learning in the field of mathematics. In this research, the students indicate that WALOD is useful for distance learning.

According to Niño-Rojas et al. (2024), mathematics teachers use web-based tools for knowledge reinforcement, problem-solving, and active learning. In this research, 94.59% of respondents believe that WALOD increases very much and much satisfaction. At significance levels of $\alpha = 0.15$ and $\alpha = 0.10$, the Mann-Whitney test indicates that the student's sex influences satisfaction through WALOD. On the other hand, the Kruskal-Wallis test shows that the age of the participants influences satisfaction.

In the study conducted by Ticse et al. (2023), internet applications such as GeoGebra boosted learning through the web simulator. Similarly, the students of Earth Sciences mentioned that the use of WALOD facilitated personalized learning about optimization based on the area of a rectangle through derivatives.

The results of the linear regression algorithm show that the use of WALOD for learning mathematics positively influences satisfaction. The function, $y = 0.401x + 1.042$, allows to predict this technological and educational phenomenon. The decision tree algorithm established that sex and age influence satisfaction through WALOD. Finally, the correlation between the use of WALOD for learning mathematics through derivatives and satisfaction is 0.377.

4.3 Creation of virtual educational spaces

Sengil-Akar and Kurtoglu-Erden (2021) indicate that the COVID-19 pandemic caused that mathematics teachers develop their technological skills to create online learning spaces. In fact, the students of the Mathematics course consider that WALOD is an innovative and interactive application.

In mathematics courses, educators create virtual environments for personalized learning and skills development using web-based tools (Niño-Rojas et al., 2024). In this research, 94.59% of participants mentioned that WALOD facilitates very much and much the creation of virtual educational spaces. At significance levels of $\alpha = 0.15$ and $\alpha = 0.10$, the Mann-Whitney test indicates that the student's sex does not influence the creation of virtual educational spaces through WALOD. On the other hand, the Kruskal-Wallis test shows that the age of the participants influences the creation of virtual educational spaces.

The findings of the research conducted by Fan et al. (2021) highlight the importance of web-based tools in mathematics education because students learn the content considering their needs. According to the respondents, mobile devices allow access to WALOD from anywhere.

The results of the linear regression algorithm show that the use of WALOD for learning mathematics positively influences the creation of virtual educational space. The function, $y = 0.700x + 0.521$, allows to predict this technological and educational phenomenon. The decision tree algorithm established the conditions considering sex and age. Finally, the correlation between the use of WALOD for learning mathematics through derivatives and creation of virtual educational space is 0.700.

Teachers are making the decision to incorporate web technology into activities because this medium promotes personalized learning, peer communication, and active participation (Guzmán-González & Vesga-Bravo, 2024; Niño-Rojas et al., 2024). During the mathematics course, WALOD offered flexibility in terms of time and location. Furthermore, the respondents indicated that this application helped learning mathematics because it is available during 365 days. Finally, WALOD facilitated distance learning due to its ease of access from any device.

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CONCLUSION

Mathematics professors can change the way of teaching and learning by incorporating technology into educational activities. The web simulator of WALOD presents the step-by-step procedure to calculate the maximum area of a rectangle through derivatives. The Mann-Whitney test indicates that the student's sex influences the use of WALOD for learning mathematics and satisfaction. However, this variable does not influence motivation and the creation of virtual educational spaces through WALOD.

On the other hand, the Kruskal-Wallis test shows that the age of the students influences the use of WALOD for learning mathematics, satisfaction, and creation of virtual educational spaces. However, this variable does not influence motivation.

The results of the linear regression algorithm show that the use of WALOD for learning mathematics positively influences motivation, satisfaction, and the creation of virtual educational space. This research recommends the use of web applications such as WALOD because students can access online content via mobile devices at any time. Furthermore, the students of Earth Science report that WALOD facilitates personalized learning about mathematics through the web simulator.

On the other hand, the decision tree algorithm used the student profile, age and sex, to determine three forecasting models on motivation, satisfaction, and the creation of virtual educational space for learning mathematics about optimization based on the area of a rectangle through WALOD. The limitations of this mixed study are the sample size and educational level of the participants. Therefore, researchers and teachers can analyze the use of educational web applications such as WALOD in middle schools, high schools, and universities.

In the field of mathematics, the practical implications about the use of WALOD include personalized learning because students can review the content at their own pace without teacher assistance, ease of use because this web application can be accessed from various digital devices, autonomy during the teaching and learning process of mathematics, and ability to resolve doubts at any time. Therefore, web simulators are an ideal technological alternative to innovate the educational context on the topics of mathematics at the upper secondary and higher levels. In conclusion, WALOD is an innovative and interactive tool that facilitates learning mathematics about optimization through derivatives from anywhere and fosters autonomy during the education process.

AUTHOR´S CONTRIBUTION

Conceptualization, R-A. S-R and L-P. A-M.; data curation, R-A. S-R. and É-P. S-R.; formal analysis, R-A. S-R. and R. C-M.; funding acquisition, R-A. S-R.; investigation, R-A. S-R., R.C-M.; É.S-M. and R-D. S-R.; methodology, R-A. S-R. and L-P. A-M.; project administration, R-A. S-R. and R-D. S-R.; resources, R-A. S-R.; supervision, R-A. S-R. and É. S-M.; validation, R-A. S-R.; writing – original draft, R-A. S-R. and É-P. S-R.; writing – review & editing, R-A. S-R. and R-D. S-R.

CONFLICT OF INTERESTS

The authors declare no conflict of interests.

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