Perceptions of students about augmented reality as a didactic resource of náhuat linguistic heritage: a case study with a control and experimental group

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ABSTRACT

This article presents the results of a study on the impact of incorporating an augmented reality textbook and android mobile applications on the teaching-learning process of the náhuat language in public schools in El Salvador. To verify the first hypothesis, statistical inference was applied to determine the significance of the mark values between the control and experimental groups through the Mann-Whitney test and Brunner–Munzel's test, previous verification of parametric assumptions of these tests, in total participated 150 students. To verify the second hypothesis, the results of student perception corresponding to the usage of the resources aforementioned, are also

RESUMEN

Percepciones de estudiantes sobre realidad aumentada como recurso didáctico de patrimonio lingüístico náhuat: un caso de estudio con un grupo de control y experimental

Este artículo presenta los resultados de un estudio sobre el impacto de la incorporación de un libro de texto de realidad aumentada y aplicaciones móviles android en el proceso de enseñanza-aprendizaje de la lengua náhuat en escuelas públicas de El Salvador. Para verificar la primera hipótesis, se aplicó inferencia estadística para determinar la significancia de los valores de las calificaciones entre los estudiantes de un grupo de control

shown, administering questionnaire surveys to 113 students in total, through two questionnaires scored on a 5-point Likert scale statements and semantic differential scale items for additional data collection related to each Likert scale statement in the questionnaire. The results show that students perceive specific advantages linked to the usage of the náhuat augmented reality textbook and mobile android applications in the náhuat language teaching-learning process. This study leads to the conclusion that students enrolled in náhuat courses in public schools in El Salvador for this case study, greatly value the teaching-learning process mediated by augmented reality technology and mobile applications.

Keywords: Augmented reality; náhuat linguistic heritage; endangered languages.

y experimental mediante la prueba de Mann-Whitney y la prueba de Brunner-Munzel, previa verificación de los supuestos paramétricos de estas pruebas, en total particparon 150 estudiantes. Para verificar la segunda hipótesis, se muestran los resultados de la percepción de los estudiantes correspondiente al uso de los recursos antes mencionados, para tal fin fueron administradas encuestas a 113 estudiantes en total, a través de dos cuestionarios con escala de Likert de 5 puntos y frases con escala de tipo diferencial semántica para la recopilación de datos adicionales relacionados para cada pregunta de tipo escala Likert antes mencionado. Los resultados muestran que los estudiantes perciben ventajas específicas vinculadas al uso del libro de texto de realidad aumentada y de aplicaciones móviles android en el proceso de enseñanza-aprendizaje de la lengua náhuat. Este estudio permite concluir que los estudiantes matriculados en cursos de náhuat en escuelas públicas de El Salvador que participaron en este estudio, valoran mucho el proceso de enseñanza-aprendizaje mediado por tecnología de realidad aumentada y aplicaciones móviles.

Palabras clave: *Realidad aumentada, herencia lingüística náhuat; lenguas en peligro de extinción.*

1. INTRODUCTION

The pipil náhuat language is a critically endangered language, as states the Atlas of the world's languages in danger (Organización de las Naciones Unidas para la Educación, la Ciencia y la Cultura [UNESCO], 2010), a study conducted by UNESCO in 2010 that proposes six degrees of endangerment for a language in the following order, safe (5), vulnerable (4), definitely endangered (3), severely endangered (2), critically endangered (1) and extinct (0).

In El Salvador, a small group of linguistic researchers has worked to safeguard the pipil náhuat linguistic heritage, including Alan Roy King, a pioneering researcher of the pipil náhuat language who wrote in 2011 the book "Timumachtikan!: Curso de lengua náhuat para principiantes adultos" (King, 2011). Another notable researcher is Werner Hernández who published in 2016 the náhuat-spanish dictionary "Nawat Mujmusta" (Hernandez, 2016), and doctor Jorge Lemus, a linguistic and researcher who wrote the textbook "Ne Nawat,

Tutaketzalis Amachti 2" (Cortéz et al., 2009), furthermore has written the paper "Un modelo de revitalización lingüística: el caso del náhuat-pipil de El Salvador" (Lemus, 2008). In this study, doctor Lemus states that there are at least 200 pipil elders who still speak the pipil náhuat language.

According to the results of another research conducted by Jorge Lemus in 2015, entitled "El pueblo pipil y su lengua de vuelta a la vida" (Lemus, 2015), there are approximately thirty eight public schools in El Salvador where the náhuat language is taught.

Since 2017, The Ministry of Education of El Salvador published the náhuat textbook "Titaketzakan Nawat!" to be used in public schools (Ministerio de Educación de El Salvador [MINED], 2017).

The náhuat cradle, is a immersive project for children, where the linguistic immersion in náhuat is intended to be total, since the approach is completely oral (Colectivo El Salvador Elkartasuna, 2023).

A Summary of the main traditional printed náhuat textbooks aforementioned, are shown in table 1.

Table 1. Summary of main traditional printed náhuat textbooks in El Salvador.

Book title	Authors	Target audience	Publication year	Reference
Ne Nawat, Tutaketzalis Amachti 2	Carlos Cortez, Jorge Lemus and Allan King	Children (three to five years old)	2009	(Cortéz et al., 2009)
Titaketzakan Nawat!	Ministry of Education of El Salvador	Children (seven to sixteen years old)	2017	(MINED, 2017)
Nawat Mujmusta	Werner Hernández	Adults	2016	(Hernández, 2016)
Timumachtikan!	Alan R. King	Adults	2011	(King, 2011)

Source: Created by the authors.

Some initiatives have been implemented using computer technologies for the safeguarding of the náhuat language in El Salvador, or other endangered languages, as listed below:

- Interactive e-book. This project was developed to reinforce literacy learning for language minority students enrolled in elementary schools (Phadung, 2015).

- Náhuatl language. This project is a website that implements an online mexican náhuatl-spanish dictionary, which has a total of 9500 mexican náhuatl terms (Valera, 2015).

- Náhuat language program. This is a website where náhuat lessons are provided, developed by Monica Ward from Ireland, in total there are twelve lessons, the content has short audio tracks (Ward, 2016).

- Náhuatl App. A mobile application focused to teach mexican náhuatl that also includes the most common greetings, the náhuatl alphabet, numbers from 1 to 100, fundamental grammar, and a word game (Juárez, 2015).

- Secwepemctsin language project. David Lacho, a master student in Canada developed an AR application to support the revitalization of the Splatsin's dialect (Lacho, 2018).

- Kusunda project. It is a interdisciplinary project for the revitalization of the linguistic heritage of the Kusunda Indigenous community in Nepal (Galeazzi et al., 2017).

1.1. Hypotheses and research objectives

AR technology has been implemented in a wide range of fields since the 1990s, engineering, education, tourism, medicine, as well as cultural heritage (Peddie, 2023), and has boosted in importance and usage since then.

Research projects have proved that this technology is useful for the preservation of cultural heritage. AR is applied in the cultural heritage field for the following benefits, a) user experience improvement on site, b) culture and language preservation (Okonovic et al, 2022), and c) revitalization (Ching, & Ong, 2023).

Research suggests that AR technology and usage of mobile applications hold vast pedagogical potential (Bower et al., 2014; Wójcik, 2020).

Taking those studies context as reference, research questions are proposed on students' perception of the implementation of the AR and mobile applications in the náhuat teaching-learning process, as well as the impact of incorporating this new didactic context generated with the usage of the AR náhuat textbook and the associated náhuat mobile applications, compared to traditional didactic resources used in public schools where the náhuat language is taught in El Salvador.

What is the impact of incorporating the new náhuat AR and android mobile resources aforementioned on the náhuat teaching-learning process and students' perception in public schools in El Salvador? Does the incorporation of these new AR resources and methodological changes entailed lead to improvements on student academic performance over traditional didactic processes used in public schools in El Salvador?

These research questions lead to a notional answer in the form of a research hypotheses summarized as follows:

Hypothesis 1: AR and mobile applications could have a positive impact on the náhuat teaching-learnig process in public schools, improving the students' academic performance.

Hypothesis 2: Incorporating AR and mobile applications, could have a positive impact on the náhuat teaching-learning process, improving students' perceptions of motivation, information quality, information richness, usability, cutting-edge technology, linguistic, language heritage promotion and dissemination, compared to traditional academic activities and printed material.

Considering the hypotheses aforementioned, this study is understood as an initial exploratory approach to implementing educational technology resources linked to the náhuat teaching-learning process applying AR and mobile applications in public schools.

Based on the analysis of the náhuat students' perception and academic students' performance, the following objectives are proposed:

a. To analyze the student's academic performance impact of incorporating an AR náhuat textbook and android mobile applications on the teaching-learning process of the náhuat language, applying statistical inference to determine the significance of the mark values between students of control and experimental groups in public schools in El Salvador.

b. To study the students' perception of the impact of implementing náhuat AR resources on the náhuat teaching-learning process, based on the following constructs and factors, motivation, information quality, information richness, usability, cutting-edge technology, linguistic, language heritage promotion and dissemination. Table 2, in section 2.5 Experimental design, shows a summary of the constructs and their indicators for data collection and data analysis listed in this objective.

2. MATERIAL AND METHOD

2.1. Náhuat AR textbook

This textbook uses images as AR markers, and through the related AR android mobile application, users get access to 2D náhuat animations in cartoon format to learn the correct náhuat pronunciation of the náhuat dialogues in a playful way, as shown in figure 1. This textbook has twenty chapters that are organized in structure as follows:, a) communicative resources, b) grammar resources, c) lexical resources, d) cultural and intercultural resources, according to the reference levels of the Cervantes Institute Curriculum Plan (Centro Virtual Cervantes [CVC], 1997).

Figure 1. AR markers for the main dialogues of chapters uno, four and five.

2.2. AR náhuat mobile application and 2D náhuat animations in cartoon format

Each of the twenty chapters of the náhuat textbook has at least one 2D náhuat animation in cartoon format as multimedia content that can be accessed using the AR náhuat mobile application as shown in figure 2.

2.3. Náhuat-spanish dictionary android mobile application

The náhuat-spanish dictionary mobile application was developed as a support resource for the náhuat AR textbook. This dictionary has four hundred náhuat entries with audio and Spanish translation, as shown in figure 3.

Figure 2. AR náhuat mobile applicatio and the respective náhuat AR textbook.

Figure 3. Náhuat-spanish dictionary android mobile application.
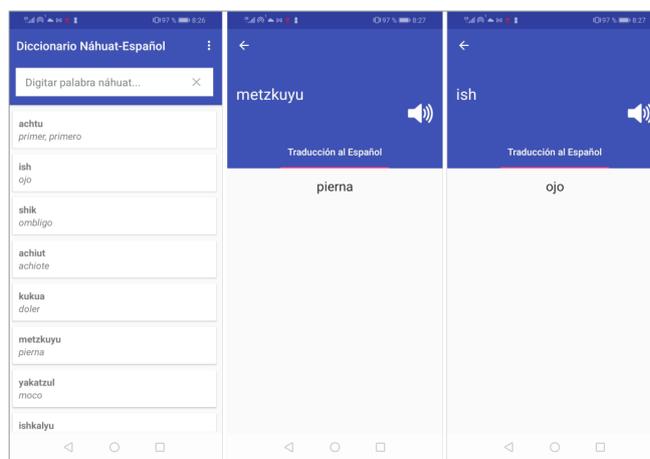
2.4. Náhuat-spanish visual dictionary mobile application

The visual náhuat-spanish dictionary mobile application was developed as a support resource for the náhuat AR textbook, each entry has un image, the spanish translation, and the náhuat pronunciation audio, as shown in figure 4.

Figure 4. Náhuat-spanish visual dictionary mobile application.
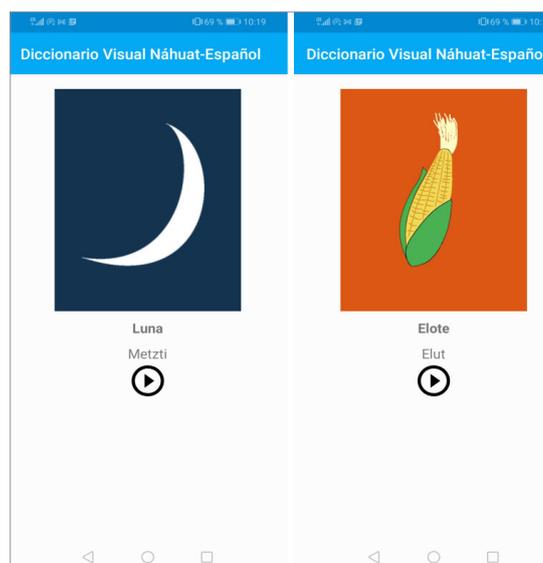
2.5. Experimental design

To verify hypothesis 1, control and experimental groups were conducted in public school Complejo Educativo Alberto Varela to corroborate the impact of incorporating an AR náhuat textbook and android mobile applications on the náhuat teaching-learning process. Statistical inference was applied to determine the significance of the mark values between the students of the control and experimental groups. This section of the research procedure employed the model proposed by Tuckman as a reference to establish experimental research with control and experimental groups (Tuckman & Harper, 34).

To verify hypothesis 2, questionnaire surveys were conducted with students in two public schools, Complejo Educativo Alberto Varela and Instituto Nacional San Luis Talpa INSAL, to analyze the students' perception of the impact of implementing the náhuat AR resources and mobile aplications on the teaching-learning process and the contribution to promoting and disseminating the náhuat language and culture. This section of the research procedure employed the model proposed by Creswell as a reference to establish a questionnaire survey study (Creswell, 2018).

Table 2 shows the constructs and their related indicators that were used for data analysis as part of the experimental design and methodology used in this study for hypothesis 1 and hypothesis 2.

Table 2. Constructs and indicators for data analysis.

Construct	Definition	Indicator	Indicator code	Data collection approach	Source
Academic performance	The degree of achievement of the educational goals that are raised in the náhuat academic program and measurable based on the mark values obtained.	Mark values	IC1	Students' mark values of control and experimental groups	(Amores & Branch, 2023; García & Pérez, 2006)
Motivation	Adequate attitude to learn, which activates in the student the necessary behaviors to achieve a learning objective.	Playfulness	IC2		(Cabero & Roig, 2019)
Information quality	The quality of the AR resources and mobile applications.	Usefulness	IC3		(Laumer et al., 2017)
		Editorial design	IC4		
		Didactic design	IC5		
Information richness	Capacity of the media to reproduce information to the target audience to better understand the information transmitted.	Interactivity and customization	IC6		(Chao et al., 2020)
Usability	The degree of ease of use of the AR resources and mobile applications.	Learning curve	IC7	Questionnaire surveys	(Johnson et al., 2022)
		Easiness	IC8		
		Efficiency of access	IC9		
		Interface design	IC10		
Cutting-edge technology	The degree of technological contribution to teach náhuat culture and language using AR resources and mobile applications.	Innovation	IC11		(Jenks, 2023)
		Suitability	IC12		
Linguistic and culture heritage promotion and dissemination	The effectiveness of the AR resources and mobile applications to contribute to the promotion and dissemination of the náhuat culture and language.	Language contribution	IC13		(Boboc et al., 2019)
		Culture contribution	IC14		

Source: Created by the authors.

2.5.1. Public school intervention participants

Intervention activities were implemented in Complejo Educativo Profesor Alberto Varela located in San Juan Talpa and also in Instituto Nacional San Luis INSAL located in San Luis Talpa, both municipalities of La Paz. Table 3 show a summary of the intervention activities conducted in both schools aformentioned.

Table 3. Participants in the intervention activities at náhuat public schools.

Public School	Intervention Activities	Náhuat materials used	Students participating in this study
Complejo Educativo Profesor Alberto Varela (CEPAV)	a) Incorporation of android mobile applications and the AR náhuat textbook in the teaching-learning process. b) Case study with two control and experimental groups. c) Two questionnaire surveys. d) Náhuat teacher interview.	Control groups a) Traditional náhuat printed materials **Experimental groups and questionnaire surveys groups** a) AR náhuat textbook in printed format.	150 students in total (CEPAV): first year high school and seventh grade students a) 73 control group students b) 77 experimental group students (also participated in questionnaire-survey activity)
Instituto Nacional San Luis Talpa (INSAL)	a) Incorporation of android mobile applications and the AR náhuat textbook in the teaching-learning process. b) Not case study with control and experimental groups, though the students used the AR resources for questionnaire surveys. c) Two questionnaire surveys. d) Náhuat teacher interview.	b) Náhuat AR android mobile application. c) Náhuat-spanish dictionary android mobile applications. d) 2D náhuat animations in cartoon format.	56 students in total (INSAL): first year high school students (participated in questionnaire-survey activity)
Total student participants for control and experimental group activities (CEPAV)			150
Total questionnaire-survey students (CEPAV and INSAL). The day of the questionnaire-survey, 20 students were absents because of covid19 pandemic			113

Source: Created by the authors.

2.5.2. Data collection conducting questionnaire surveys in two náhuat public schools

Two questionnaire surveys were conducted with a total of 113 students in the public schools aformentioned, as shown and summarized in detailed in table 3.

The questionnaires surveys employed in this research were ad hoc instruments; the design was based on research methods in education, following Bisquerra's recommendations (Bisquerra, 2014), and based on developing questionnaires for educational research, following Diaz-Barriga's recommendations (Diaz-Barriga, 2014).

The questionnaire surveys consisted of Likert-style statements, all used a 5-point scale: a) strongly agree, b) agree, c) neutral, d) disagree, and e) strongly disagree. Also, additional items in differential semantic style were used to investigate the reasons that led to choosing the respective answer for each question in Likert-style format in the questionnaire (McCartan & Robson, 2016).

Two questionnaire surveys were conducted to obtain students' feedback at both public schools, corresponding to information related to the following resources and materials used in this study:

a. Náhuat AR textbook and AR android mobile application.

b. Náhuat-spanish dictionary android mobile application.

Reliability was also calculated using Cronbach's alpha coefficient (Taber, 2018), the scores achieved are the following as shown in figure 5:

a. 0.86 for the questionnaire survey related to the náhuat AR textbook and the AR android mobile application.

b. 0.83 for the questionnaire survey related to the náhuat-spanish dictionary android mobile applications.

Once the questionnaires were structured, those were administered in the classroom of both aforementioned public schools, where seventh grade students and high school students participated.

Figure 5. Cronbach's alpha coefficient of the two questionnaire surveys.
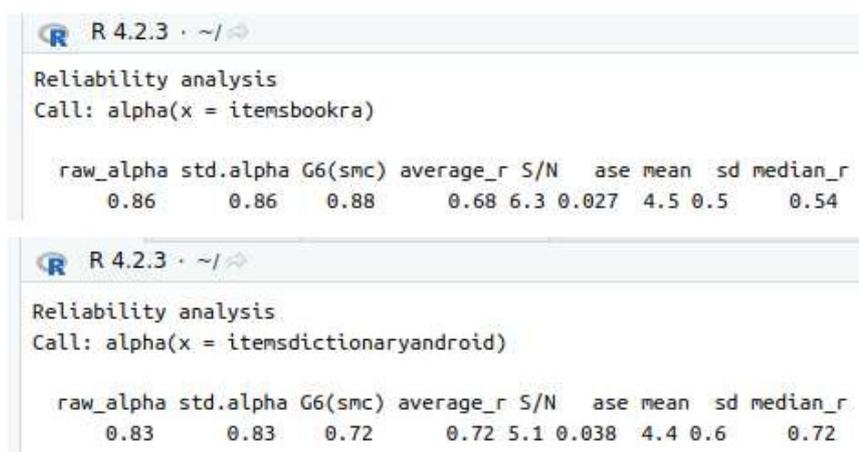
2.5.3. Mark values of control and experimental groups in a náhuat public school

The Intervention activity for control and experimental groups were conducted in the academic year 2022, from march to november. A total of one hundred and fifty students participated in this case study. All the participating students were neophytes in the náhuat language.

The control groups used in the teaching-learning process, the traditional náhuat textbook edited and published by the Ministry of Education of El Salvador, a náhuat textbook that has been used since 2017 by thirty eight public schools in El Salvador.

All experimental groups incorporated in the teaching-learning process, the AR náhuat textbook, the náhuat AR android mobile application and the náhuat-spanish dictionary android mobile applications.

The náhuat classes were taught over a period of ten months, two hours per week, this comprises a maximum of eighty hours of náhuat learning in the classroom during the academic year 2022.

2.5.4. Data collection conducting an interview with the náhuat teacher

As part of the experimental design using a case study approach, the náhuat teacher was interviewed, he stated the following main ideas respect to the intervention activities implemented in the náhuat public schools:

a. This is the first time that AR technology is used to teach the náhuat language and its culture at public schools in El Salvador.

b. Based on his 17-year experience teaching náhuat language the teacher stated that this is the first time that 2D náhuat cartoon animation are used to teach the náhuat language.

c. This multimedia contribution is very important due to the nature of the content of these 2D animated videos, since the students had access to the pronunciation of the náhuat dialogues, present in the AR textbook in an playful way that contribute positively in the teaching-learning process, motivating the students to learn this endanger language, since these multimedia resources reinforce the linguistic skills of listening comprehension and speaking.

d. Resources developed in the past to teach the náhuat language, only had audio files or no other sound digital media as multimedia resources.

3. RESULTS

All the statistical analyses were conducted using Rstudio 4.2.3 for Linux.

3.1. Control and experimental group statistical analysis

In education research, comparisons between two groups are frequently made to demonstrate that one group has better performance than the other (McMillan & Schumacher, 2005).

To verify hypothesis 1, statistical inference was applied to determine the significance of the mark values between the control and experimental groups through the Mann-Whitney test and Brunner–Munzel's test, both tests are nonparametric approaches (Karch, 2023).

Although the Welch's t-test and Student's t-test are the preferred parametric tests for this purpose (García & Pérez, 2019), in this study, non-parametric methods were necessary to be applied, because the mark values of three student groups, exhibited a distribution distinct from a normal distribution, that is, a continuous probability distribution that is symmetrical around its mean with most values near the central summit of the curve (Tejedor & Etxeberria, 2006). Both Welch's t-test and Student's t-test have the following main assumptions, a) data is continuous, b) homogeneity of variance, c) data have a normal distribution (Bonilla, 1992).

Once the parametric assumptions were verified for the mark values of the control and experimental groups using the Shapiro-Wilk test and Levene test respectively (Asencio, 2017), a decision was taken to applied the Mann-Whitney test and Brunner–Munzel's test instead, since the data did not complied with the assumptions required by the Welch's t-test and the Student's t-test.

Mann-Whitney test and Brunner–Munzel's test have the following mean assumptions, a) data is continuous, b) homogeneity of variance and c) normal distribution is not required.

3.1.1. Results of high school groups

Seventy-three participants were high school students with an average age of fifteen, the control group was comprised of thirty-five students, and the experimental group thirty-eight students. Both experimental and control groups do not comply with normal distribution required by Welch's t-test and Student's t-test, verified by the box plot and density plot, shown in Figure 6. To reinforce this result of no normal distribution, the Shapiro-Wilk test was applied. The p-value of Shapiro-Wilk test of both data sets (see figure 7), experimental and control

groups, are less than 0.05 that verifies no compliance of normal distribution. The Levene's test (see figure 8) is applied to check compliance of the homogeneity of variances assumption for both nonparametric tests aforementioned, the p-value is greater than 0.05, this means that this data set meets the homogeneity of variance test.

As the mark values do not have normal distribution, the next stage was the application of the Mann-Whitney test as inferential statistics nonparametric approach, the null hypothesis was set to analyze if the experimental group have greater mark values than the control group since the modifier alternative="greater" is used, the p-value analyzed is less than 0.05 (see figure 8).

To reinforce this result, also the nonparametric Brunner–Munzel's test is applied, as shown in Figure 9. This outcome also supports the results obtained with the Mann-Whitney test, that is, the experimental group have greater mark values than the control group, and the significant difference is confirmed in favor of the experimental group.

Figure 6. Box plot and density plot for experimental and control groups of first year high school.
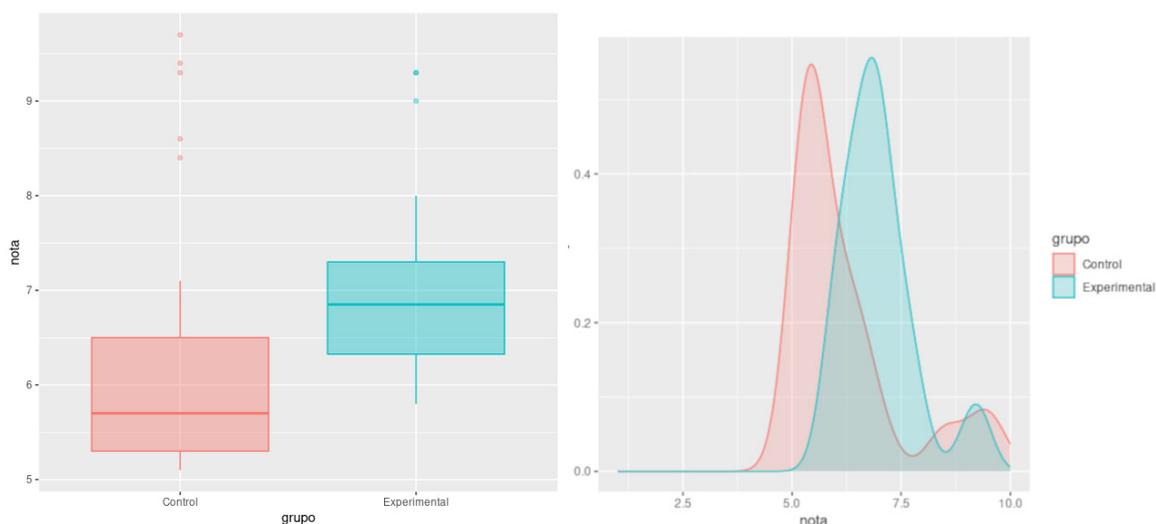
Figure 7. Shapiro-wilk normality test results for experimental and control groups (first year high school students).


```
Console   Terminal ×   Background Jobs ×

ℝ   R 4.2.3 · ~/ ⇗

> shapiro.test(experimental$nota)

        Shapiro-Wilk normality test

data:  experimental$nota
W = 0.88558, p-value = 0.001024
```

```
Console   Terminal ×   Background Jobs ×

ℝ   R 4.2.3 · ~/ ⇗

> shapiro.test(control$nota)

        Shapiro-Wilk normality test

data:  control$nota
W = 0.75599, p-value = 3.121e-06
```
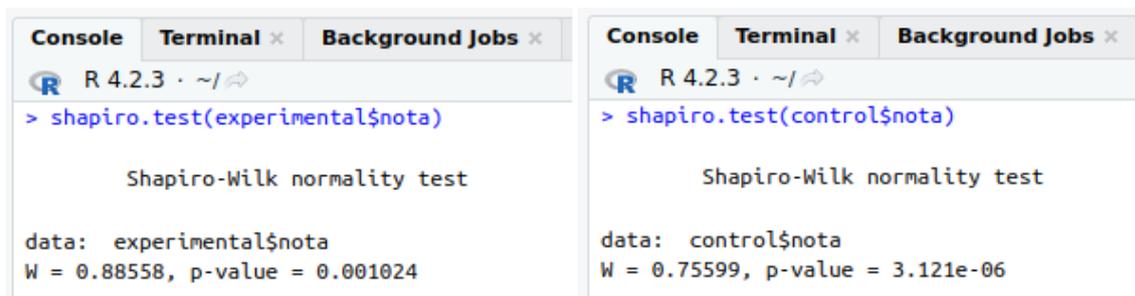
Figure 8. Levene test, Wilcoxon test and mean summary results for experimental and control groups (first year high school students).

Figure 9. Brunner-Munzel test results for experimental and control groups of first year high school.

3.1.2. Results of the seventh grade groups

Seventy-seven participants were seventh grade students with an average age of twelve; the control group was comprised of thirty-eight students, and the experimental group thirty-nine students.

Both experimental and control groups do not comply with normal distribution required by Welch's t-test and Student's t-test, verified by the box plot and density plot, shown in

Figure 10. To reinforce this result of no normal distribution, the Shapiro-Wilk test was applied. The p-value of Shapiro-Wilk test of both data sets (see figure 11), experimental and control groups, are less than 0.05 that verifies no compliance of normal distribution. As the mark values of the experimental group do not have normal distribution, the next stage in this data analysis was the application of Mann-Whitney test and Brunner–Munzel's test as inferential statistics nonparametric approaches.

The Levene's test (see figure 12) is applied to check compliance of the homogeneity of variances assumption for both nonparametric tests aforementioned, the p-value is greater than 0.05, this means that this data set complies with the homogeneity of variance test.

Applying the Mann-Whitney test (see figure 12), the null hypothesis was set to analyze if the experimental group have greater mark values than the control group since the modifier alternative="greater" is used, the p-value analyzed is greater than 0.05.

To reinforce this result, also the Brunner–Munzel's test is applied (see figure 13), the p-value analyzed is greater than 0.05, again the modifier alternative="greater" is used, this outcome also supports the results obtained with the Mann-Whitney test, that is, there is not significant difference between both, experimental group and control group for seventh grade student mark values.

Figure 12 shows that the experimental group have greater mark values than the control groups, since the mean values are 6.13 and 5.79 respectively, but according to inferential statistics that difference is not significant statistically.

Figure 10. Box plot and density plot for experimental and control groups of seventh grade students.
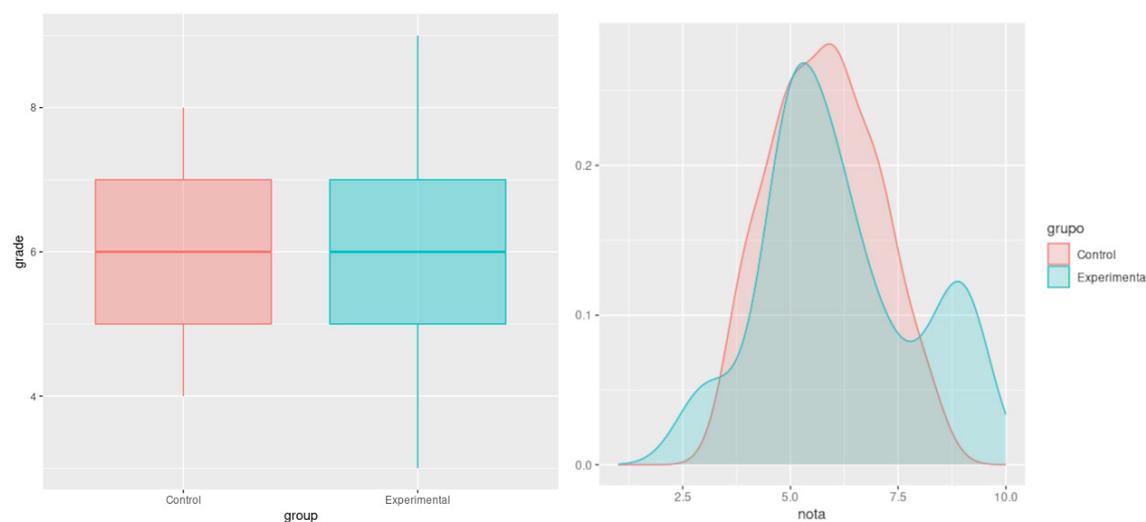
Figure 11. Shapiro-wilk normality test results for experimental and control groups of seventh students.
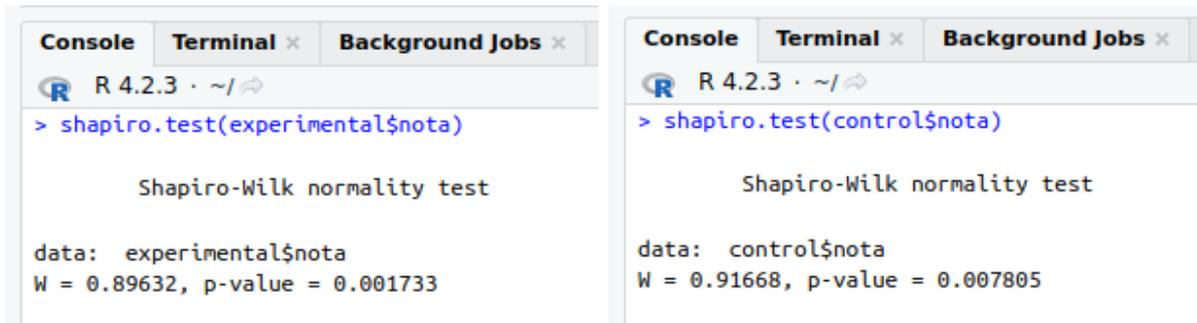
Figure 12. Box Shapiro-wilk normality test results for experimental and control groups of seventh students.
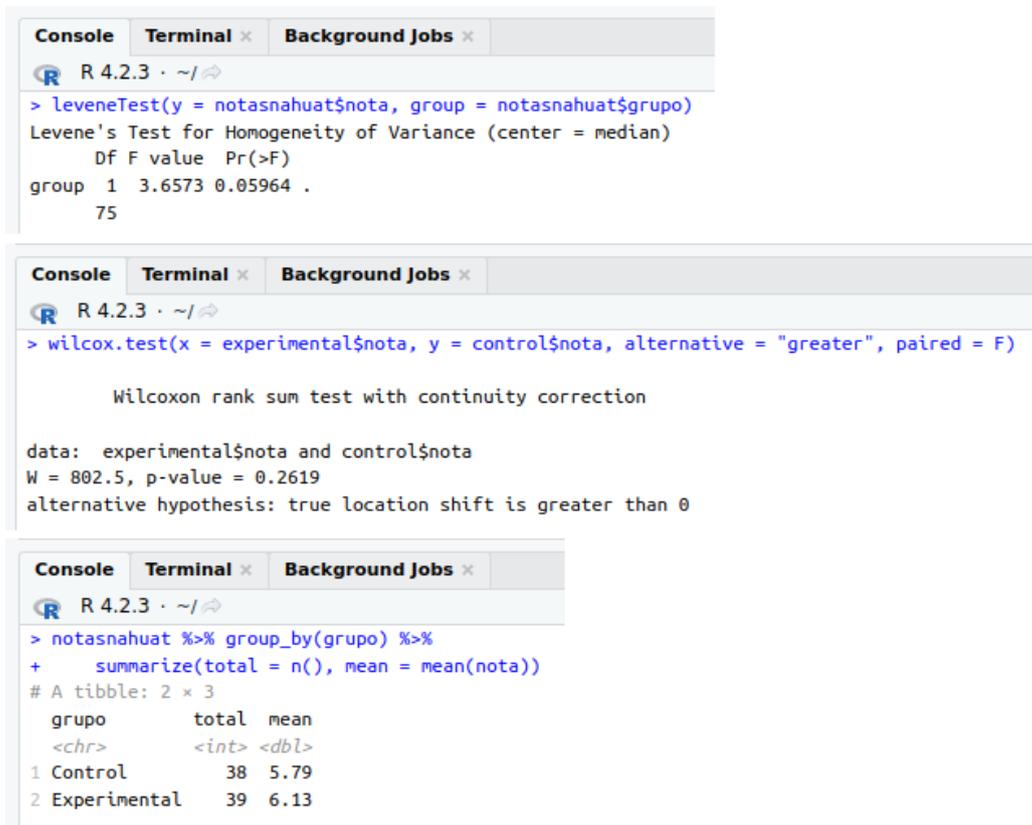
Figure 13. Brunner-Munzel test results for experimental and control groups of seventh grade students.

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R  R 4.2.3 · ~/
> brunnermunzel.test(x = experimental$nota, y = control$nota, alternative = "greater")

        Brunner-Munzel Test

data:  experimental$nota and control$nota
Brunner-Munzel Test Statistic = -0.63591, df = 69.918, p-value = 0.2635
95 percent confidence interval:
 0.3283478 0.5886562
sample estimates:
P(X<Y)+.5*P(X=Y)
        0.458502
```

Table 4. Summary control and experimental groups at Complejo Educativo Profesor Alberto Varela. Source: Created by the authors.

Náhuat group	Result	Nonparametric approach
High school students	The experimental group had greater mark values than the control group, and the significant difference is confirmed in favor of the experimental group, as shown in figure 10, according to inferential statistics.	Mann-Whitney and Brunner–Munzel's tests
Seventh grade students	According to inferential statistics, there was not significant difference between both, experimental group and control group as shown in figure 14, even though the experimental group have greater marks values than the control groups according to descriptive statistics, since the mean values are 6.13 and 5.79 respectively.	

3.2. Questionnaire surveys data analysis

For the questionnaire surveys, the analysis was focused on students' perception based on the constructs and their related factors listed and explained in table 2. In total participated 113 students of both public schools, summarized in detailed in table 3. Two questionnaire surveys were administered and organized as follows:

a. Questionnaire survey for náhuat AR textbook and AR android mobile application.

b. Questionnaire survey for náhuat-spanish dictionary android mobile application.

After answering each Likert-style statement present in the two questionnaire surveys, the students were asked to select one or more reasons through a list of differential semantic style statements to support the answer selected for the Likert-style statement, as shown in figure 14, that summaries the questionnaire survey data analyses approach.

Figure 14. Questionnaire survey data analysis general approach diagram.
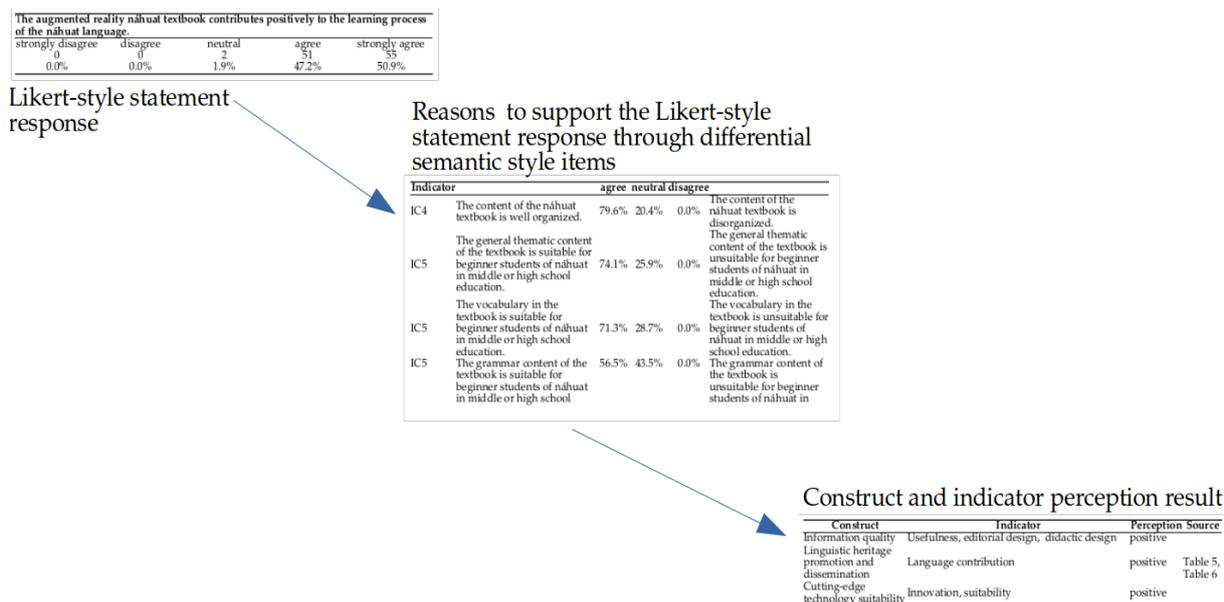
3.2.1. Questionnaire survey for the náhuat AR textbook and AR android mobile application

Question 1. Table 6 shows the descriptive statistics of Likert-style statement for question 1. Most students' responses indicate a positive perception since 47.2% and 50.9% have answered that they agreed and strongly agreed respectively, also the standard deviation of this question was low, which indicates that the responses were tightly clustered around the mean value. Table 5 shows a summary of these results for question 1 and for the respective responses of the linked semantic differential style statements (see Table 7).

Table 5. Perception summary for question 1.

Likert Statement	Construct	Indicator	Perception	Source
Question 1	Information quality	Usefulness (IC3), editorial design (IC4), didactic design (IC5)	Positive	Table 6, Table 7
	Information richness	Interactivity and customization (IC6)	Positive	
	Linguistic heritage promotion and dissemination	Language contribution (IC13)	Positive	
	Cutting-edge technology suitability	Innovation (IC11), suitability (IC12)	Positive	

Source: Created by the authors.

Table 6. Descriptive statistics for Likert-style statement, question 1.

The augmented reality náhuat textbook contributes positively to the learning process of the náhuat language						
Strongly disagree	Disagree	Neutral	Agree	Strongly Agree	Mean	Stándard Deviation
0	0	2	51	55	4.49	0.54
0.0%	0.0%	1.9%	47.2%	50.9%		

Source: Created by the authors.

Table 7. Descriptive statistics for semantic differential statements related to Likert-style statement response for question 1.

Indicator		Agree	Neutral	Disagree	
IC4	The content of the náhuat textbook is well organized.	79.6%	20.4%	0.0%	The content of the náhuat textbook is disorganized.
IC5	The general thematic content of the textbook is suitable for beginner students of náhuat in middle or high school education.	74.1%	25.9%	0.0%	The general thematic content of the textbook is unsuitable for beginner students of náhuat in middle or high school education.
IC5	The vocabulary in the textbook is suitable for beginner students of náhuat in middle or high school education.	71.3%	28.7%	0.0%	The vocabulary in the textbook is unsuitable for beginner students of náhuat in middle or high school education.
IC5	The grammar content of the textbook is suitable for beginner students of náhuat in middle or high school education.	56.5%	43.5%	0.0%	The grammar content of the textbook is unsuitable for beginner students of náhuat in middle or high school education.
IC3	The dialogues of each chapter are very useful for learning the náhuat language.	71.3%	26.9%	1.9%	The dialogues of each chapter are useless for learning the náhuat language.
IC13	The textbook has adequate content to disseminate aspects of the náhuat culture.	50.0%	50.0%	0.0%	The textbook has unsuitable content to disseminate aspects of the náhuat culture.
IC4	The textbook has a graphic design suitable for students of middle education or high school education.	50.0%	48.1%	1.9%	The textbook has a graphic design unsuitable for students of middle education or high school education.
IC2	The textbook uses augmented reality technology that facilitates the learning of the náhuat language in an entertaining way.	61.1%	38.9%	0.0%	The textbook uses augmented reality technology which makes it difficult the learning of the náhuat language in an entertaining way.
IC12	The textbook uses augmented reality technology, which has happened to be suitable for learning the náhuat language.	50.9%	49.1%	0.0%	The textbook uses augmented reality technology, which has happend to be unsuitable for learning the náhuat language.
IC6	The textbook has animations of náhuat dialogues in 2D cartoon format, which facilitates the learning of the náhuat language in an entertaining way.	59.3%	38.9%	1.9%	The textbook has animations of náhuat dialogues in 2D cartoon format, which makes difficult the learning of the náhuat language in an entertaining way.
IC11	The textbook is innovative because it uses augmented reality technology.	58.3%	41.7%	0.0%	Although the textbook uses augmented reality technology, it lacks innovation.
IC11	The textbook is innovative because it has an augmented reality android mobile application.	54.6%	45.4%	0.0%	Although the textbook has an augmented reality android mobile application, it lacks innovation.
IC11	The textbook is innovative because it has náhuat-spanish dictionary android applications.	55.6%	42.6%	1.9%	Although the textbook has náhuat-spanish dictionary android applications, it lacks innovation.

Source: Created by the authors.

Question 2. Table 9 shows the descriptive statistics of Likert-style statement for question 2. Most students' responses indicate a positive perception since 45.4% and 48.1% have answered that they agreed and strongly agreed respectively, also the standard deviation of this question was low, which indicates that the responses were tightly clustered around the mean value. Table 8 shows a summary of these results for question 2 and for the respective responses of the linked semantic differential style statements (see Table 10).

Table 8. Perception summary for question 2.

Likert Statement	Construct	Indicator	Perception	Source
Question 2	Usability	Learning curve (IC7), easiness (IC8), efficiency of access (IC9)	Positive	Table 9, Table 10

Source: Created by the authors.

Table 9. Descriptive statistics for Likert-style statement, question 2.

The náhuat augmented reality mobile application is easy to use for the user						
Strongly disagree	Disagree	Neutral	Agree	Strongly Agree	Mean	Stándard Deviation
0	0	7	49	52	4.42	0.61
0.0%	0.0%	6.5%	45.4%	48.1%		

Source: Created by the authors.

Table 10. Semantic differential statements related to Likert-style statement response for question 2.

Indicator		Agree	Neutral	Disagree	
IC7	The learning process requires less than 5 minutes.	51.9%	38.0%	10.2%	The learning process requires more than 5 minutes.
IC8	It is easy to access the náhuat 2D animations in cartoon format, which are associated with the printed náhuat textbook.	74.1%	21.3%	4.6%	It is difficult to access the multimedia content of 2D náhuat dialogues in cartoon format, which are associated with the printed náhuat textbook.
IC9	The augmented reality mobile application allows access to 2D náhuat animations in cartoon format, efficiently and quickly.	79.6%	16.7%	3.7%	The augmented reality mobile application is slow, which makes it difficult to access the 2D náhuat animations in cartoon format.

Source: Created by the authors.

Question 3. Table 12 shows the descriptive statistics of Likert-style statement for question 3. Most students' responses indicate a positive perception since 50.0% and 44.4% have answered that they agreed and strongly agreed respectively, also the standard deviation of this question was low, which indicates that the responses were tightly clustered around the mean value.

Table 11 shows a summary of these results for question 3 and for the respective responses of the linked semantic differential style statements (see Table 13).

Table 11. Perception summary for question 3.

Likert Statement	Construct	Indicator	Perception	Source
	Motivation	Playfulness (IC2)	Positive	
Question 3	Information quality	Didactic design (IC5)	Positive	Table 12, Table 13
	Linguistic heritage promotion and dissemination	Language contribution (IC13)	Positive	

Source: Created by the authors.

Table 12. Likert-style statement for question 3.

The 2D náhuat animations in cartoon format contribute positively to the learning process of the náhuat language						
Strongly disagree	Disagree	Neutral	Agree	Strongly Agree	Mean	Stándard Deviation
0	0	6	54	48	4.39	0.59
0.0%	0.0%	5.6%	50.0%	44.4%		

Source: Created by the authors.

Table 13. Semantic differential statements related to Likert-style statement response for question 3.

Indicator		Agree	Neutral	Disagree	
IC2	The 2D náhuat animations present the content of the náhuat dialogues in an entertaining way.	81.5%	16.7%	1.9%	The 2D náhuat animations present the content of the náhuat dialogues in an uninteresting way.
IC13	The audio of the dialogues contribute to knowing how the náhuat language is pronounced.	69.4%	30.6%	0.0%	The audio of the dialogues in the náhuat language is incorrect or inefficient.
IC13	The audio of the dialogues contribute to learning the correct pronunciation of the náhuat language.	62.0%	37.0%	0.9%	The audio of the dialogues contributes little to learning the correct pronunciation of the náhuat language.
IC5	The dialogues of the 2D animations teach useful vocabulary.	52.8%	44.4%	2.8%	The dialogues of the animations teach deficient or unhelpful vocabulary.
IC13	The dialogues of the 2D animations contribute to having a first approach to the náhuat language.	54.6%	45.4%	0.0%	For his deficient contribution to contribute to having a first approach to the náhuat language.
IC5	The themes of the dialogues contribute to learning the fundamentals of the náhuat language.	67.6%	31.5%	0.9%	Because the themes of the náhuat dialogues are deficient, which make it difficult to learn the fundamentals of the náhuat language.

Source: Created by the authors.

3.2.2. Questionnaire survey for the náhuat-spanish dictionary android mobile application

Question 1. Table 15 shows the descriptive statistics of Likert-style statement for question 1. Most students' responses indicate a positive perception since 55.8% and 36.4% have answered that they agreed and strongly agreed respectively, also the standard deviation of this question was low, which indicates that the responses were tightly clustered around the mean value. Table 14 shows a summary of these results for question 1 and for the respective responses of the linked semantic differential style statements (see Table 16).

Table 14. Perception summary for question 1.

Likert Statement	Construct	Indicator	Perception	Source
Question 1	Usability	Learning curve (IC7), easiness (IC8) , interface design (IC10)	Positive	Table 15, Table 16

Source: Created by the authors.

Table 15. Likert-stye statement for question 1.

The náhuat-spanish dictionary mobile application is easy to use for the user						
Strongly disagree	Disagree	Neutral	Agree	Strongly Agree	Mean	Stándard Deviation
0	0	6	43	28	4.25	0.65
0.0%	0.0%	7.8%	55.8%	36.4%		

Source: Created by the authors.

Table 16. Semantic differential statements related to Likert-style statement response for question 1.

Indicator		Agree	Neutral	Disagree	
IC7	The learning process requires less than 5 minutes.	53.2%	39.0%	7.8%	The learning process requires more than 5 minutes.
IC8	It is easy to translate words from náhuat to spanish.	76.6%	16.9%	6.5%	It is difficult to translate words from náhuat to spanish.
IC10	It is easy to navigate between the windows or interfaces of the mobile application.	62.3%	35.1%	2.6%	It is difficult to navigate between the windows or interfaces of the mobile application.
IC10	The colors used in the design of the different windows or interfaces of the mobile application have appropriate contrast, the colors are suitable.	31.2%	63.6%	5.2%	The colors used in the design of the different windows or interfaces of the mobile application have deficient contrast, the colors are unsuitable.
IC10	The design of the different interfaces of the mobile application is appropriate, because the different components or links of the navigation system are well organized.	49.4%	46.8%	3.9%	The design of the different interfaces of the mobile application is inappropriate, because the different components or links of the navigation system are disorganized.
IC10	The text used in the different interfaces of the application is appropriate in size for the correct usage.	62.3%	36.4%	1.3%	The text used in the different interfaces of the application is inappropriate in size, this makes it difficult to use it correctly.

Source: Created by the authors.

Question 2. Table 18 shows the descriptive statistics of Likert-style statement for question 2. Most students' responses indicate a positive perception since 35.1% and 53.2% have answered that they agreed and strongly agreed respectively, also the standard deviation of this question was low, which indicates that the responses were tightly clustered around the mean value. Table 17 shows a summary of these results for question 2 and for the respective responses of the linked semantic differential style statements (see Table 19).

Table 17. Perception summary for question 2.

Likert Statement	Construct	Indicator	Perception	Source
Question 2	Information quality	Didactic design (IC5), usefulness (IC3)	Positive	Table 18, Table 19
	Cutting-edge technology used	Innovation (IC11), suitability (IC12)	Positive	
	Linguistic heritage promotion and dissemination	Language contribution (IC13)	Positive	

Source: Created by the authors.

Table 18. Likert-style statement for question 2.

The náhuat-spanish dictionary mobile application contributes positively to the learning process of the náhuat language						
Strongly disagree	**Disagree**	**Neutral**	**Agree**	**Strongly Agree**	**Mean**	**Stándard Deviation**
0.0%	0.0%	11.7%	35.1%	53.2%	4.26	0.59
0	0	9	27	41		

Source: Created by the authors.

Table 19. Semantic differential statements related to Likert-style statement response for question 2.

Indicator		Agree	Neutral	Disagree	
IC5	The vocabulary of the náhuat-spanish dictionary is suitable for náhuat beginner students in middle or high school education.	93.5%	6.5%	0.0%	The vocabulary in the náhuat-spanish dictionary is unsuitable for náhuat beginner students in middle or high school education.
IC13	Each náhuat term or word has its corresponding audio that makes it easy to learn the pronunciation of the náhuat language.	67.5%	27.3%	5.2%	Each náhuat term or word has its corresponding audio, this makes it difficult to learn the pronunciation of the náhuat language.
IC3	The available audio of each term or word in náhuat is correctly pronounced.	55.8%	41.6%	2.6%	The available audio of each term or word in náhuat is incorrectly pronounced.
IC5	The náhuat-spanish dictionary android mobile application has more than 400 náhuat words or terms, suitable for beginner students of the náhuat language.	68.8%	27.3%	3.9%	The náhuat-spanish dictionary android mobile application has more than 400 náhuat words or terms, but are insufficient for beginner náhuat students.

Indicator		Agree	Neutral	Disagree	
IC11	The náhuat-spanish dictionary android mobile application is innovative because it is the first dictionary mobile application currently available for learning the náhuat language.	20.8%	74.0%	5.2%	The náuat-spanish dictionary android mobile application lacks innovation, because there are already dictionary mobile applications for learning the náhuat language.
IC12	Because it is free, this dictionary android mobile application is available to everyone.	58.4%	39.0%	2.6%	Although it is a free dictionary android mobile application, it has the drawback that it is deficient.
IC5	This software application is very useful to learn the náhuat language, as a dictionary mobile application to support the náhuat augmented reality textbook.	66.2%	32.5%	1.3%	This software application is unsuitable to learn the náhuat language, as a dictionary mobile application to support the náhuat augmented reality textbook.

Source: Created by the authors.

4. DISCUSSION

This study analyzed students' academic performance of two pedagogical models, one based on traditional methodology and traditional náhuat printed materials and the other based on implementing a náhuat AR textbook and android applications.

As well, this study aimed to analyzes students' perceptions in terms of motivation, information quality, information richness, usability, cutting-edge technology, linguistic language heritage promotion and dissemination, based on a pedagogical model that implemented AR and android mobile applications, in náhuat courses that took place at Complejo Educativo Profesor Alberto Varela and Instituto Nacional San Luis INSAL.

The results obtained provide evidence that the use of AR, mobile applications and 2D video animations in this náhuat educational context improves some of the different aspects under analysis. Findings of previous studies support the results obtained in the intervention activities in náhuat public schools in El Salvador.

Previous studies have shown that the implementation of educational technology didactic resources in teaching-learning processes, based on AR and mobile aplications, leads to methodological changes that students perceive as beneficial compared to traditional teaching and learning environments based on printer materials (Moreno et al., 2020; Kalogiannakis et al., 2021).

In the field of AR, research focused on students' perceptions of technological teaching approaches and AR technology, offers similar conclusions, considering that their usage could

have a beneficial effect on the teaching–learning process. Students in general perceive it as a technological didactic approach that supports their learning process, in the sense of hence being able to stimulate their learning and improve their motivation (Sofianidis, 2022).

As well, previous research has emphasized the pedagogical and didactic potential of visualizing parts of the real world through a mobile device with multimedia information incorporated by AR technology (Lucena, 2022; Cabero & Barroso, 2016; AlNajdi, 2022).

The results show that students perceived specific advantages linked to the usage of the náhuat AR textbook and mobile android applications in the náhuat language teaching-learning process, related to the following constructs, a) motivation, b) information quality, c) information richness, d) usability, e) cutting-edge technology, f) linguistic and culture heritage promotion and dissemination.

5. CONCLUSIONS

With this pedagogical model that has been discussed in this study and implemented in the náhuat courses of two public schools, a door has been opened to improve the teaching learning-process of the náhuat language and culture heritage of the pipil ancestors in El Salvador, using cutting-edge technologies such as AR, android mobile applications, and also multimedia content such as 2D animations in cartoon format, all those resources and the didactic methodological approach were designed and developed, aimed to motivate students to learn the náhuat endangered language, also to promote and disseminate this linguistic and culture heritage in thoses public schools in El Salvador.

This study contributes to a better understanding of the náhuat students' perception of didactic resources based on the usage of AR resources and mobile applications in the náhuat teaching-learning process, focused on the constructs, a) motivation, b) information quality, c) information richness, d) usability, e) cutting-edge technology, f) linguistic and culture heritage promotion and dissemination. Also these náhuat students great values the teaching learning process mediated by augmented reality and mobile applications.

When placing this study's discussion and conclusions in context, the findings also showed a lack of didactic experiences and research related to the pedagogical use of AR and mobile applications in El Salvador in general, and emphasizing the náhuat teaching-learning process, reflecting a gap with other countries.

6. FUNDING

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