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Intelligent tutoring system based on personalized learning for teaching health care protocols

Sistema tutor inteligente basado en la personalización del aprendizaje para la enseñanza de protocolos de atención en salud

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Abstract: Personalization of learning is a process that organizes system contents considering user characteristics and performance using Artificial Intelligence. This article aims to present the design and evaluation of an Intelligent Tutoring System (ITS) for personalized learning through pedagogical strategies based on Case-Based Reasoning about care protocols for gestational and congenital syphilis. The methodology used in this research was quasi-experimental with two groups, experimental and control. The sample consisted of 68 students. The experimental group was the only one that used the ITS, while the control group received training through lectures. The group that used the ITS obtained better learning achievement than the other group that traditionally learned this topic. These results could suggest that the use of this type of applications, in health education, would facilitate the creation of new learning scenarios that enable meaningful learning considering the characteristics and needs of students.

Keywords: Health Education, Pedagogical Strategy, Personalized Learning, Case-Based Reasoning, Intelligent Tutoring System.

Resumen: La personalización del aprendizaje es un proceso que organiza los contenidos del sistema considerando las características y desempeño de los usuarios utilizando Inteligencia Artificial. Este artículo presenta el diseño y evaluación de un Sistema Tutor Inteligente para la personalización del aprendizaje a través de estrategias pedagógicas basadas en Razonamiento Basado en Casos sobre protocolos de atención para sífilis gestacional y congénita. La metodología fue cuasiexperimental con dos grupos, experimental y control. La muestra estuvo conformada por 68 estudiantes. El grupo experimental utilizó el STI, mientras que el grupo control recibió la formación a través de clases magistrales. El grupo que utilizó el STI obtuvo un mejor logro de aprendizaje frente al otro grupo que aprendió tradicionalmente este tema. Estos resultados podrían sugerir que el uso de aplicaciones de este tipo, facilitaría la creación de nuevos escenarios que permitan un aprendizaje significativo considerando las características y necesidades de los estudiantes.

Palabras clave: Educación para la salud, Estrategia pedagógica, Personalización del aprendizaje, Razonamiento basado en casos, Sistema tutor inteligente.

1. INTRODUCCIÓN

Personalized learning has become, in recent years, a key feature in the development of intelligent systems for education [1]–[3], allowing to organize system contents according to individual user needs and performance through Artificial Intelligence (AI) techniques [4], considering course objectives and strategies implemented by teachers [3], [5]. These AI techniques adapt content according to student individualities by deciding the most appropriate learning resources from different alternative representations, emulating the adaptation strategies commonly associated with instructional design experts [6]–[10]. When the learning adaptation process is carried out in a personalized way, the system generally performs an adaptive personalization process of pedagogical strategies [2], [4], [11], [12]. In Intelligent Tutoring Systems (ITS), a pedagogical strategy is an instructional plan that sequences and organizes instructional content considering learning activities, presentation form, student profile, learning pace, and interaction with the system [13], [14]. The process of pedagogical strategy personalization in ITS can be performed from different approaches [5]. The most common approach executes the personalization from the use of stereotypes or student profiles [15], [16]. That approach groups students based on their performance history and general information (e.g., learning styles). A monitoring process performed by the system facilitates the tracking of the student's interaction with the resources (assessment score, frequency of use, etc.) and the score obtained in partial and final evaluations, reflected in terms of successful and unsuccessful cases, used by the system each time other students make use of it. [17]. For this reason, the most used technique in this type of pedagogical strategy personalization is Case-Based Reasoning (CBR) [18], [19].

Several authors have proposed numerous studies on the personalization of learning in ITS [6], [12], [12]. Some of them have carried out this process of personalization of learning from pedagogical strategies [4], [7], [12], using different AI techniques and from different knowledge domains [8], [20], [21]. Although other authors have developed ITS to generate learning processes that take into account user characteristics in health education [7], [20]–[22], [23], [24]–[32] and others have created intelligent systems for teaching about various diseases [20], [21], [24], [29], none of them have developed ITS for learning care protocols of gestational and congenital syphilis, using adaptive personalization processes of pedagogical strategies through CBR.

There are high rates of gestational and congenital syphilis infection in the department of Córdoba-Colombia [33]. In addition, in the educational institution where this study was implemented, students have low levels of learning in care protocols for this diseases [33], which is considered a public health problem) [34]. Therefore, the objective of this article is to present the design and evaluation of an ITS for personalized learning through CBR-based pedagogical strategies about care protocols for gestational and congenital syphilis. This article is framed within the context of health education, where the development of personalized and adaptive intelligent systems that considers the needs and interests of the student are conceived as a pressing challenge [35].

This article is structured as follows: first, the ITS model for personalized learning is presented, then, the methodology implemented in this study, third, the results are described and finally, the conclusions, acknowledgements and references.

2. ITS FOR PERSONALIZED LEARNING IN GESTATIONAL AND CONGENITAL SYPHILIS

An ITS is a computational system that offers instruction through AI techniques oriented to granular learning experiences [3], [36], facilitating the adaptability of learning from the specific needs or knowledge level of students. An ITS is structured in four basic components [27], [28], [29], an expert module, student module, tutor module and user interface [30]-[34]. Because the ITS seeks to offer personalized instruction [35], [36], its main module is the tutor module [35], [37], [38], also known in the literature as the instructional planner [27], [39], [40]. The learning objectives and pedagogical strategies that guide the student's learning process [41], [12], [42], [43] are held in the pedagogical model of the tutor module. The pedagogical model determines how the ITS adapts its pedagogical strategies in the form of instructional plans [27], [40], [21]. These plans comprise the strategies developed by an instructional designer to achieve learning objectives in students through individual learning resources.

The achievement of the objectives in ITS is reached through learning lessons that comprise the pedagogical strategies which in turn are configurable tools by the system's personalization process (Bahg, 2021). Each lesson consists of educational resources that take into account the characteristics of the student, the pedagogical objectives and the learning context [2], [4]. Therefore, the process of personalizing pedagogical strategies in ITS is very complex [4], [12], which requires the use of intelligent algorithms that organize the learning resources according to the individual needs of the students and their performance [2], [4]. According to [2] the intelligent algorithms allow developing the process of personalizing pedagogical strategies in ITS from a granular approach, where students are grouped according to their specific characteristics and interaction data to offer an increasingly personalized learning experience. Among the most widely used algorithms for this type of personalization is CBR. This AI technique tries to solve problems using knowledge from previous experiences in similar cases. In this research, an ITS has been developed on care protocols for gestational and congenital syphilis that personalizes pedagogical strategies using CBR, which will be described below. The ITS based its architecture on the Metagogic metamodel which was designed to guide the development of ITS with adaptive personalization characteristics of pedagogical strategies [4]. Figure 1 represents the relationship between the packages that make up the ITS developed in this research. This metamodel states that the Planner package (tutor module) of the ITS hosts the personalization algorithms of the system.

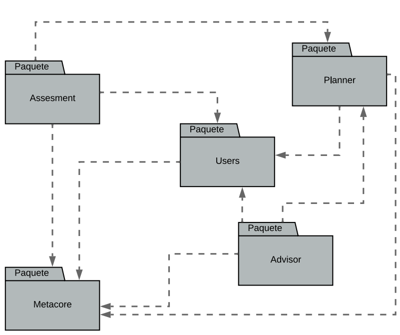

Fig. 1. *Packages of the Metagogic metamodel.*
Source: *Own elaboration.*

Figure 2 exemplifies the classes that make up the Planner package of the ITS developed in this study. The tutor package selects the most appropriate Pedagogical Strategy for each student. A Pedagogical Strategy is a plan composed of a Context (general data about Student, Course, Lesson), a Pedagogical Approach (Learning Theories and Teaching Methods) and a Learning Activity (content of a Lesson that defines the Pedagogical Tactics and Learning Resources).

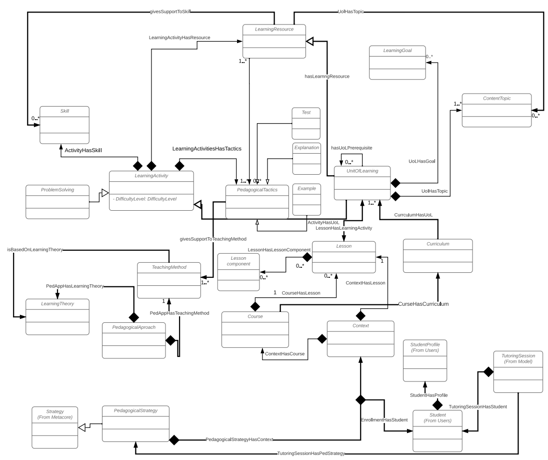

Fig. 2. *Structure of the ITS Planner package.*
Source: *Own elaboration.*

In the ITS, Pedagogical Tactics are defined as components of a lesson (Introduction, definition, description, example, activity and evaluation) and these require Learning Resources to be developed. This Pedagogical Strategy class also hosts the CBR algorithm in charge of selecting them. Next, Table 1 describes the basic high-level control flow of this algorithm.

Tabla 1: *CBR algorithm for the selection of pedagogical strategies in Metagogic. Own elaboration*

Code	Comments
procedure CBR (ε)	
$\gamma_n \leftarrow \mu.new()$	◂ New temporal case
$\rho(\varepsilon, \gamma_n)$	◂ CBR cycle step 1st
$\gamma_n \leftarrow \alpha(\gamma_n, \upsilon.pref.t_r, \upsilon.pref.\ e_r)$	◂ CBR cycle step 2nd
$\sigma(\kappa\ (\gamma_n))$	◂ CBR cycle step 3rd
procedure $\rho\ (\varepsilon, \gamma_t)$	
for $i \leftarrow 0$ **to** $\mu(EOF)$	◂ Search in memory
if $\gamma_{t_{[i]}}.\varepsilon = \varepsilon$ **and** $\gamma_{t_{[i]}}.p_e = \max(\mu.p_e)$ **then** $\gamma_t \leftarrow \gamma_{t_{[i]}}$	
$Planner\ (\gamma_t)$	◂ Case execution

10: **procedure** $\alpha\ (\gamma_t, t_r, e_r)$
11: $\gamma_t.t_r \leftarrow t_r$ ◂ Case time
12: $\gamma_t.e_r \leftarrow e_r$ ◂ Case assessment
13: $return\ (\gamma_t)$
14: **procedure** $\kappa\ (\gamma_t)$
15: **if** $\gamma_t.t_r \geq \min(\mu.t_r)$ **and** $\gamma_t.e_r > 3$ **then**
16: $\gamma_t.state \leftarrow successful$ ◂ Successful case
17: **else**
18: $\gamma_t.state \leftarrow unsuccessful$ ◂ Unsuccessful case
19: $return\ (\gamma_t)$
20: **procedure** $\sigma\ (\gamma_t)$
21: $\mu.modify(\gamma_t)$ ◂ Case saving

The algorithm creates a new case γn (line 2) and starts the CBR process step cycle (line 3) with the Retrieval step ρ, which requires the student's learning style ε and the created case as input data. This step performs a search in the case memory μ (line 7) according to the learning style of the case and choosing the most similar case with the highest euclidean weight p_e stored in the case memory (using the k-neighbors algorithm), to then execute it in the interface through the Planner package. Once executed, the adaptation step α (line 4) assigns the usage time t_r that the student makes of the case and its evaluation e_r, to then return it with these new assignments (line 13). The verification step κ corroborates the conditions to catalog a case as successful or unsuccessful (line 15). For the case to be considered successful, its interaction time with the user must be the minimum time available in memory and its evaluation must be greater than 3 points. Finally, the case is stored in the case memory in the storage step σ (line 5).

The Pedagogical Approach is configured from the context of the pedagogical strategy, so it is possible to have an individualized pedagogical approach for each student. Many studies have used Metagogic for the development of ITS with adaptive personalization of pedagogical strategies [7], [11], [12], [37], [38]. For this, different AI techniques have been used: Rule-based reasoning [11], Goal-Directed Autonomy [12], [37], cognitive algorithms [7], among others. However, none of these have implemented CBR as the reasoning mechanism of the system's Planner package. The ITS architecture offers personalized learning paths in real time, based on the Felder-Silverman learning style model [39], the dynamic and progressive change in student behavior during the learning process, and the previous successful learning experiences of other students. These features are used to maximize the behavior of the CBR algorithm, which has been selected due to its inherent ability to maintain prior knowledge in its repository and reuse past maintained knowledge. Furthermore, Metagogic has a data structure that facilitates the behavior of CBR algorithms for user profiling (User package), learning style classification (Learning Styles and Learning Progress module), student monitoring and tracking (Performance and Preference Trace module), resource time and evaluation (Learning Resource module in the Planner package), selection of pedagogical strategies (Pedagogical Strategies Module in the Planner package) and representation of pedagogical strategies as instructional plans (Plan Module in the Metacore package). All these advantages are evidenced in the empirical results of this study.

The programming languages used for the development of the ITS were JavaScript and Python. MongoDB was used as the database manager and VueJS was the framework used for the interface design. The ITS is available at the following web address (https://fichasyprotocolosensalud.com/)

3. METHODOLOGY

This research followed a quasi-experimental design with two groups (experimental and control). Both groups were administered a Pre-test and Post-test to identify the level of learning [17]. The two groups were randomly formed, in this case the control group consisted of 36 students and the experimental group of 32 students. These groups had similar characteristics and were under the responsibility of the professor in charge of the course chosen for the study. The experimental group was the only group that used the ITS, while the control group developed the contents guided by the pedagogical strategies of the professor. The experience was carried out over 30 days with two-hour synchronous sessions daily and students could access the system asynchronously freely at other times. This study was applied with students enrolled in the Maternal and Child course, 68 students, 57 women and 11 men whose ages ranged between 21 and 28 years.

For the development of the study, four phases were determined which are described below. The first phase consisted of a process of familiarizing the students with the research, presenting its objectives and activities. Additionally, an informed consent was signed by the students who wished to participate in the study. To conclude this phase, an initial interaction session with the ITS was developed. The second phase included the application of the Pre-Test, which was implemented to the two research student groups, during a time of 30 minutes. It should be noted that the Pre-Test was a questionnaire consisting of 10 multiple choice questions with a single answer. Pre-Test was previously developed and validated in the framework of the research. The results of the validation process are presented below. The Cronbach's Alpha coefficient was applied, obtaining a result of 0.773, which evidenced the strong relationship between the questions and the high level of reliability of the instrument. In addition, the sphericity adequacy was performed with the KMO measures (0.652) and Bartlett's test (82.54 with 45 degrees of freedom and associated with a significance value less than 0.001). This verifies a good level of relationship between the variables of the instrument. The third methodological phase of the study was the application of the ITS to the experimental group. A computer room consisting of 35 computers was made available daily for a period of two hours. Students who did not finish the course unit could continue developing it outside the tutoring session. As for the control group, the same teacher continued the thematic development as usual. The last phase of the research was the application of the Post-test, which consisted of a ten-question multiple-choice questionnaire similar to those posed in the Pre-test. The instrument was also previously developed and validated within the framework of the research. The results of its validation are Cronbach's Alpha coefficient with a value of 0.796, KMO measures (0.622) and Bartlett's test (112.01 with 45 degrees of freedom and associated with a significance value less than 0.000).

4. RESULTS

In order to carry out a detailed analysis of the results obtained from the application of the instruments, a one-way ANOVA test was implemented with its respective analyses of assumption fulfillment and the respective multiple comparisons of the scores of each test with a Tukey test. The latter was done with the intention of determining if the Post-Test presented a better score than the Pre-test and thus better student performance after using the ITS.

4.1. Mean Difference Test

For the comparative analysis, some descriptive statistics were performed for the students in the sample, using the scores obtained from the Pre-Test and Post-Test instruments, as well as the confidence intervals for the mean score of each test.

***Table 2:** Classification of discrimination for the pre and post-test items in the control and experimental groups.*
Source: Own elaboration.

Test	Group	N	Mean	SD	Var. Coef.	Confidence interval	
Pre-Test	Control	36	6,6	1,2	17,1%	6,1	6,9
	Experimental	32	6,3	1,4	21,5%	5,8	6,8
Post-Test	Control	36	7,9	1,1	12,2%	7,7	8,3
	Experimental	32	9,2	0,9	8,4%	8,9	9,5

In Table 2, it can be observed that while the means and confidence intervals for the control and experimental groups tend to be similar during the Pre-Test, an increase in the average score is observed when performing the Post-Test. Additionally, a difference between the mean result of both groups is evident, highlighting better performance for the experimental group.

4.2. Analysis of Variance

To confirm the behavior described above, an analysis of variance was performed between the results of the control and experimental groups with respect to the Post-Test that was conducted under controlled conditions. A completely randomized design was defined, and the following result was obtained given the hypotheses:

1) H_0: *There are no significant differences between the means of the different groups.*
2) H_1: *At least one pair of means are significantly different from each other.*

Thus, a one-way ANOVA test was applied, obtaining as a result a non-significant p-value (p-value >0.05) for the average score of the students at the time of taking the Pre-Test and forming the control and experimental groups, which allows establishing the non-existence of a statistical difference between the average values of the scores of the tests taken by the students that make up each study group (see Figure 3).

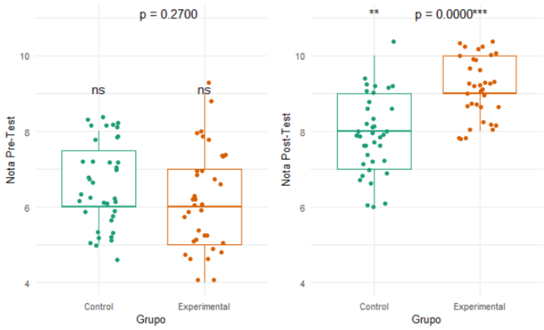

Fig. 3. *Analysis of variance for the test scores in each of the groups.*
Source: *Own elaboration.*

Observing Figure 3 on its right side, the rejection p-value (p-value<0.05) of the null hypothesis for the final Post-Test score is confirmed, which leads to rejecting it and affirming with 95% confidence that on average the Post-Test score is higher in one of the study groups, control or experimental. Similarly, when performing the Kruskal-Wallis test as a non-parametric alternative to not necessarily adjust the data to a normal distribution, a p-value of 9.396e-07 is found which is less than 0.05 and the significance of the difference in the two groups is confirmed.

Therefore, it was necessary to perform multiple comparisons of the scores applying Tukey's test. This was done with the intention of knowing which test had the best result, whether before or after applying the ITS.

Tukey's Multiple Comparisons Test (Post-Hoc Contrast)
As the null hypothesis H0 of equality of means was rejected in the analysis of variance (ANOVA), it was investigated how these results differ through the multiple comparisons test with Tukey's test, using the following hypotheses.

$$\begin{cases} H_0: \mu_j = \mu_{j'} \\ H_1: \mu_j \neq \mu_{j'} \end{cases}$$

For t treatments, there are a total of t(t - 1)/2 comparisons with test statistic for each of the hypotheses of the corresponding difference in absolute value between their sample means. In this way, it was found that they are different and that on average the Post-Test scores for the selected students are higher than those of the Pre-Test with a confidence level of 95%, as can be observed in Figure 4.

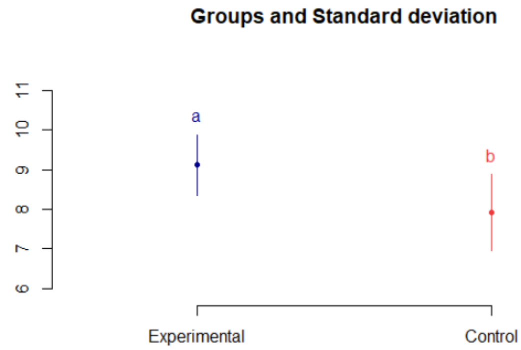

Fig. 4. *Comparison of the average values of the control and experimental groups of the scores for the Post-Test applying Tukey's test.*
Source: *Own elaboration.*

From Figure 4 it can be inferred that, considering the test scores of each group, the Post-Test for the experimental group has less variability as observed in the descriptive analysis and that its score differs and is higher than that of the Post-Test taken by the control group.

It should be noted that, although both average scores increased for the Post-Test in each group, for the experimental group it was higher and also statistically differs from that of the control group. Furthermore, as a non-parametric measure to confirm that these two groups differ, the Holm method is used, having a p-value of 9.7e-07, thus confirming the significant difference.

4.3. Validation of Assumptions for Analysis of Variance

Verification of the assumptions of the analysis of variance ensures that the model used is adequate for the analysis.

4.3.1. Normal Distribution of Residuals
This assumption establishes that the residuals must be normally distributed ei ~ N(0,1). Next, a density curve observed from the frequencies of the residuals and the normal probability plot are presented, considering that the observed density curve resembles the Gaussian bell curve, and that, in the normal probability plot, the observed quantiles of the residuals of the variable of interest approximate the central line representing the quantiles of a theoretical normal distribution, so there are no indications of non-compliance with the assumption of normality (see Fig. 5).

1) H_0: *The residuals of the score variable come from a normal population.*
2) H_1: *The residuals of the score variable do not come from a normal population*.

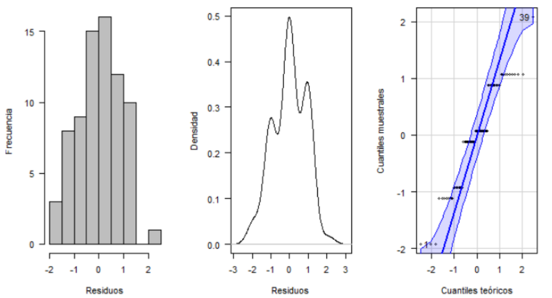

Fig. 5. *Histogram, density and theoretical quantiles vs sample quantiles for the residuals.*
Source: *Own elaboration*

To have certainty of the fulfillment of this assumption, the Shapiro-Wilk test was performed, finding a p-value of 0.00032 and, therefore, the null hypothesis is rejected, because the p-value is less than the significance level value (alpha=0.05), so it is concluded that the residuals of the variable of interest are not normally distributed with mean zero and constant variance. Therefore, the response by the Kruskal-Wallis test is assumed with more confidence as a non-parametric statistic and therefore the significant difference between the test groups can continue to be assumed.

4.4. Independence of Residuals

This assumption requires that the probability that the residual of any observation has a certain value should not depend on the values of the other residuals. In theory, this was fulfilled by randomizing the treatments, but the Durbin-Watson (DW) test was performed to have certainty of the fulfillment of this assumption. It should be taken into account that, if the value of the DW statistic is close to 2 then the residuals are not auto-correlated. If its value is 0 there is perfect positive autocorrelation. If it has a value of 4 there is perfect negative autocorrelation. When performing the residual independence test of the scores, it was determined that the residuals are not correlated, because the DW is close to 2 (2.1803) and the p-value=0.4960 is higher than the alpha significance level of 0.05, so it is concluded that there is independence of the residuals.

5. CONCLUSION

The ITS proposed in this article presents full functionality by integrating an adaptive personalization model of pedagogical strategies with the CBR technique in its tutor module, from a specific field of health education: Teaching care protocols for gestational and congenital syphilis. For this, an adaptation of the CBR algorithm was developed in such a way that it took advantage of the potentialities of the Metagogic metamodel. The results of this study provide a first approach to personalized learning in this specific topic of health education. These results indicate that the group that used the ITS obtained better learning achievement compared to the other group that learned this subject in a traditional way. This could suggest that the use of this type of applications, in health education, would facilitate the creation of new learning scenarios that enable meaningful learning according to the characteristics and needs of students. The ITS described in this article provides health professionals with a personalized learning tool that they can access at any time and place.

Considering the above, as future work, the creation of a computational system for personalized learning that uses Machine Learning techniques is proposed, which when implemented in this type of population can be compared with the system proposed in this study and thus verify if the technique used for learning personalization influences the learning achievement of students.

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