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A recommendation system for teaching strategies according to learning styles

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ABSTRACT

Teaching strategies (TS) are resources, procedures, techniques, and/or methods that teachers use as instruments to promote meaningful learning in students and that have proven to be efficient as support in classroom teaching. This paper describes a recommendation system (RS) for teaching strategies according to learning styles (RSTSLS) that helps to determine the most appropriate TS to use according to the learning style (LS) of the students based on Felder and Silverman's learning styles model (FSLSM). A working example of the system is provided, as well as the results of its functional and non-functional tests, which were satisfactory. It is concluded that the system can be useful as a support tool for teachers, allowing them to adapt their TS according to the LS of their students.

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1. INTRODUCTION

In recent years, studies related to the teaching-learning process within the educational field have increased significantly. Among them are those related to teaching strategies (TS) and learning styles (LS), which have become elements of great importance in achieving quality teaching.

Li *et al.* [1] and Robinson *et al.* [2] define LS as "the complex way in which, and the conditions under which, learners most effectively perceive, process, store, and remember what they are trying to learn". TS are a set of decisions that teachers make to guide teaching in order to promote student learning. They are general guidelines on how to teach disciplinary content taking into account what teachers want students to understand, why, and what for [3], [4].

Getting students to learn is one of the main objectives of a teacher. However, it is something that is not always achieved. Even if everyone is taught the same thing in the classroom, the end result is not always what is expected. One of the main causes of this problem is that the TS that are put into play for students to learn is not always the most appropriate for their LS. According to Munna and Kalam [5], LS is a very important element to promote quality teaching. Knowing the predominant LS of the students at a given moment is fundamental to adapt the TS to their characteristics and achieve better results in their performance. Therefore, it is not enough for teachers to have an in-depth knowledge of the technical aspects of the subject they teach. It is also necessary that they have tools that allow them to achieve the expected learning of students.

One of these tools can be recommendation system (RS), which according to Ricci *et al.* [6] and Kar *et al.* [7], is a set of information retrieval techniques that attempts to discover the interest of users in

certain objects, in order to offer them a set of related objects associated with their profile. In line with the above, this type of software can be oriented to recommend TS based on the profile of the students and their LS, which could make it an important support tool for teachers.

In recent years, researchers and some software development companies have introduced software for research or commercial purposes that allows teachers to know the LS of their students to somehow adapt their courses to them. Sprock *et al.* [8] show the development of an instructional technique RS based on pedagogical objectives that incorporate the instructional techniques most appropriate to the cognitive processes involved in the students' learning objectives proposed by the teacher, and to the student's LS. The proposed model is based on Felder and Silverman's cognitive model of LS and basic thinking processes.

Bautista *et al.* [9] develop a classification system of educational resources based on the user's profile, which considers their LS and the competencies that the student gathers from upper secondary education. This system will be a tool to find the most appropriate educational resources for students according to their profile and the generic competencies of upper secondary education. The search is performed in a repository included in the system, which contains different types of educational resources with their respective metadata. These metadata, together with the weight assigned in the classifier system, allow retrieving the educational resources most appropriate to the student's profile.

Dorça *et al.* [10] show an efficient approach to personalize the teaching process based on LS. This approach is based on an expert system that implements a set of rules that classify learning objects according to their teaching strategy or style and filters learning objects according to students' LS.

Herran *et al.* [11] develop a content-based RS that, based on the student's LS, determines and recommends activities according to the strategies that best fit their profile. The proposal was validated in two universities in Colombia and in dissimilar subjects; The results are promising and can be applied in different courses and in virtual, blended, and face-to-face environments.

Although today there are several proposals that address this problem from different perspectives, we can still find some gaps that can be studied in the development of tools that support this process, among them:

a) Incorporate models for obtaining LS that have been shown to be effective in the literature associated with the subject but have been little used by the software developed to date.
b) Recommend the most appropriate TS based on the LS identified.
c) Cross-platform compatibility to cover a wider range of modern computing devices.

In line with the above, in this way, this paper presents a teaching strategies RS according to LS based on Felder and Silverman's LS model that recommends the most appropriate TS according to student's LS. The proposed RSTSLS was developed as a responsive angular web application with support for adapting to multiple computing devices such as computers, tablets, and cell phones. To obtain students' LS and based on them recommend the most appropriate TS to the teacher, it implements FSLSM [12], [13], which is a LS model designed for traditional learning and a preferred one in adaptive educational hypermedia and technology-enhanced learning [14]. In the case of the recommended TS according to the LS found, these were selected and chosen according to what is indicated in various specialized research publications associated with the subject [15]-[18].

2. SOFTWARE DESCRIPTION

In this section we describe the RSTSLS, the details of its implementation, functionalities and illustrative examples of use. The software is composed of two subsystems, a learning styles detection subsystem (LSDS) that helps to identify the learning styles of a learner or groups of learners and a teaching strategies recommendation subsystem (TSRS) that are implemented using a three-tier architecture. The first is oriented to be used by students and the second by teachers.

The software is available for download at https://github.com/jfFigueroa23/SIREEEA under a GPL-3.0 license, which, among other things, provides the freedom to use, study, share and modify them as deemed appropriate, and protects them from appropriation attempts that restrict those freedoms to new users whenever they are distributed, modified or extended. It has been designed with a user interface that aims to be intuitive and simple so that inexperienced users can easily adapt and use it [19].

2.1. Architecture

Figure 1 shows the three-tier architecture of RSTSLS. The data layer is where the information processed by the application is stored and managed. The application layer is the heart of the software, where information is processed using business logic. The presentation layer is the user interface where the end user interacts with the application [20], [21].

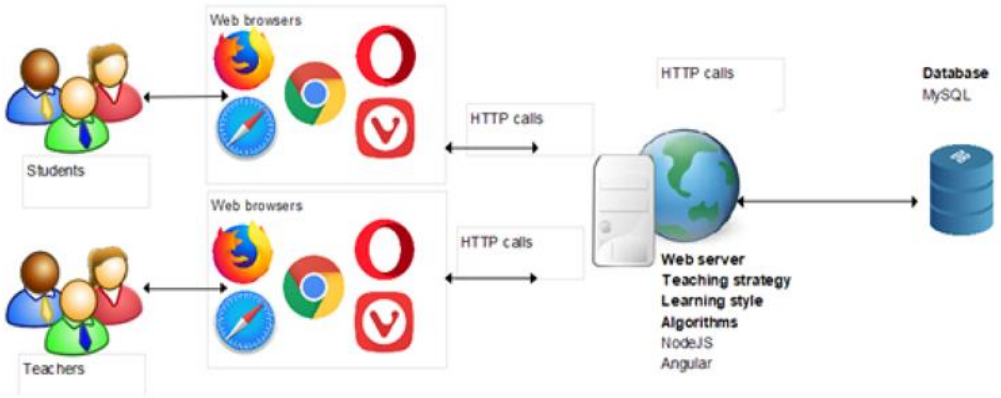

Figure 1. RSTSLS architecture

Both LSDS and TSRS use various technologies that are distributed in each of the levels of the architecture (see Figure 1): a) The data level is a MySQL database to store user information, individual questionnaires and LS according to the FSLSM [22]; b) The application level was built with NodeJS, Angular and Typescript and contains the algorithms to determine the LS of the students and recommend the TS to the teachers [23]; c) The presentation level and contains screens to capture information and show results to users and is composed of the classic elements of a website with HyperText markup language (HTML), cascading style sheet (CSS) and Javascript [24].

2.2. Functionalities

Currently, the main functions of the software include:

- Capture of the FSLSM LS screening questionnaire.
- LS detection per user or user group according to FSLSM.
- Storage and retrieval of the FSLSM questionnaire and its results by user or groups of users.
- Determination of the most appropriate TS according to the predominant LS per user or group of users.
- Determination of the TS by groups according to the predominant LS in each student or group of students.
- Recommendation of the set of the TS according to the LS identified.

2.3. Illustrative examples

This section guides the user on how to use the software correctly, as well as to learn about its features and objectives. Figure 2 shows the login screen of the RSTSLS system, where the user must specify whether he/she is a student or a teacher and provide his/her access data.

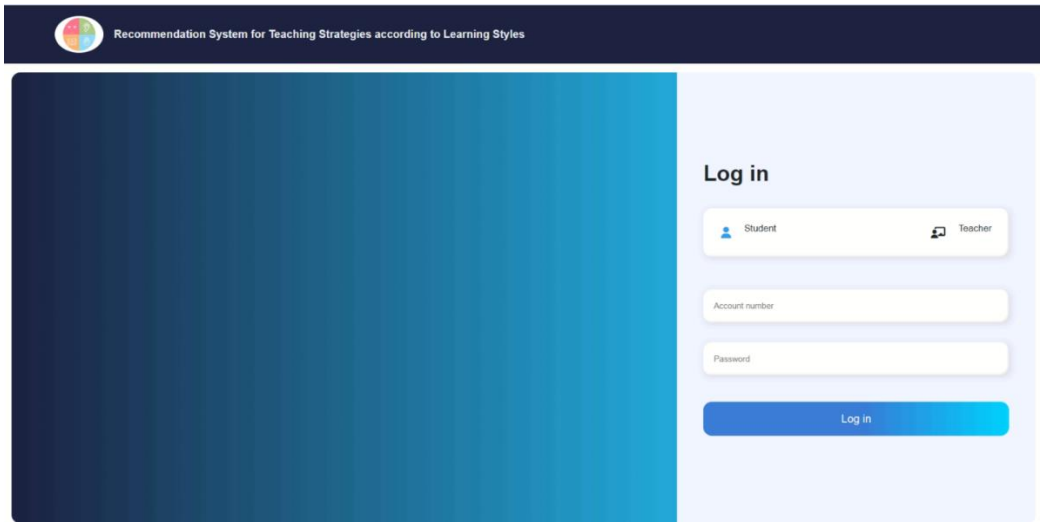

Figure 2. RSTSLS login screen

2.3.1. LSDS subsystem

Once the above is done, if the user is a student, the LSDS main screen shown in Figure 3 is displayed. Here the user can start answering the FSLSM questionnaire by clicking on the "Star survey" button if he/she has not done so previously, answer the questionnaire again if desired, or view the results previously obtained. If the user decides to answer the FSLSM questionnaire, the system displays the screen to capture his 44 questions. A fragment of this screen is shown in Figure 4.

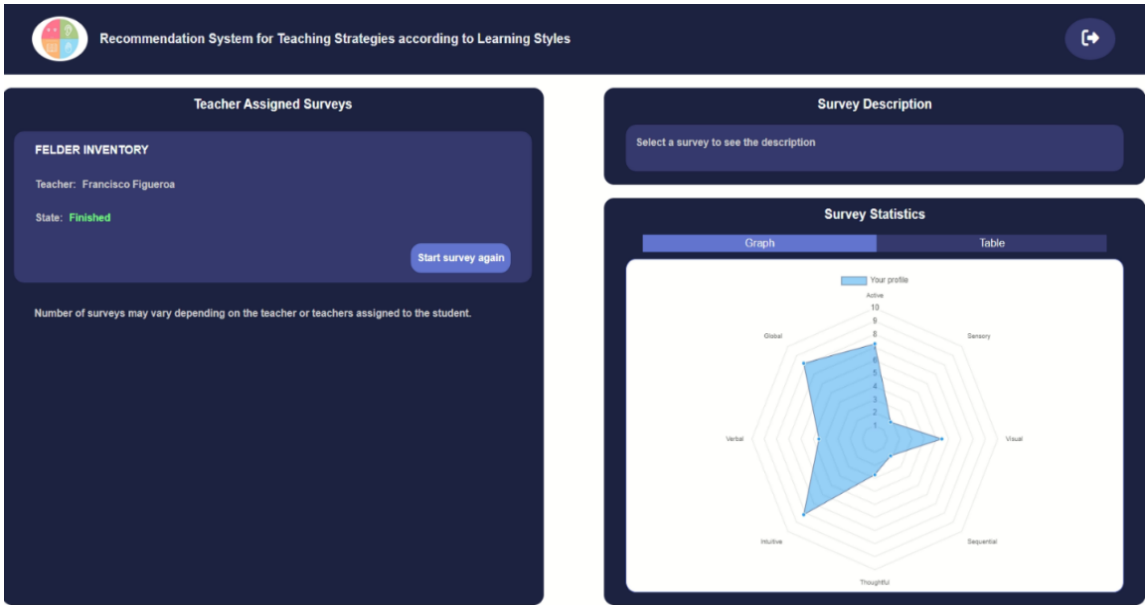

Figure 3. Main screen of the LSDS

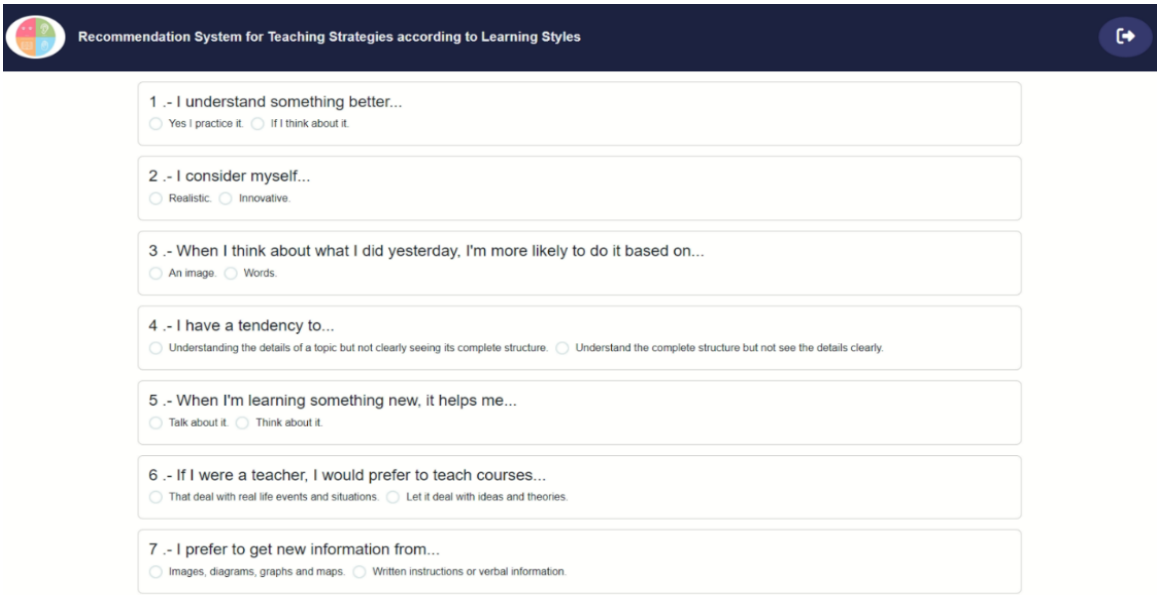

Figure 4. FSLSM questionnaire (fragment)

When the user has answered the questionnaire, the system displays the results in graphical or tabular form. Figures 5 and 6 show the results provided by the LSDS of the LSs identified for the current user. In the case of the user taken as an example, it is observed that the trends in each of his processing, perception, input and comprehension dimensions are "Active", "Sensory", "Visual", and "Global" respectively.

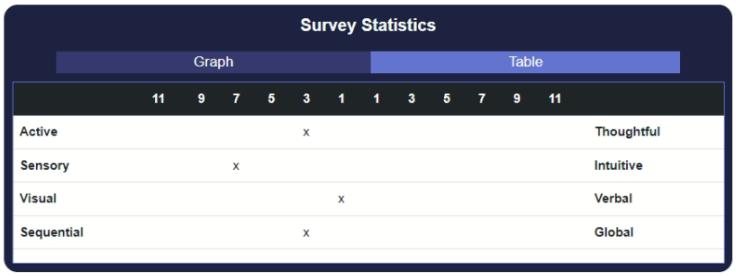

Figure 5. LSDS results in tabular form

Figure 6. LSDS results in graphical form

2.3.2. TSRS subsystem

As for TSRS, Figure 7 shows the main screen of the system once the teacher logs in. The system is intended to be used by teachers once the students' LSs have been determined using the LSDS. Here, the user can view individual or group teaching strategy recommendations or download associated reports.

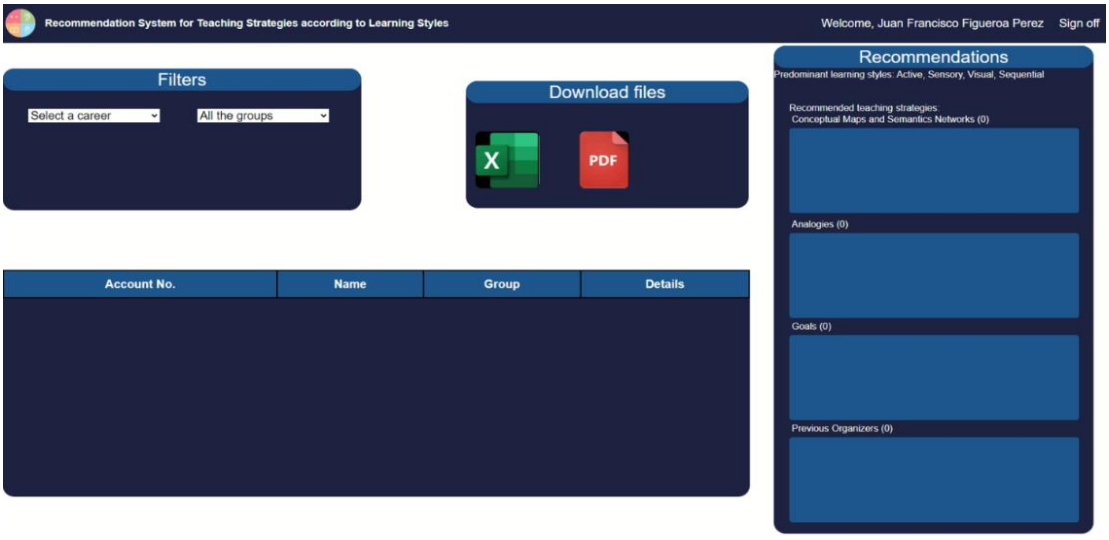

Figure 7. TSRS main screen

3. METHODS

3.1. LSDS evaluation

To test the LSDS subsystem, non-probabilistic samples were taken by convenience from the total population of students of the Software Engineering program of the Engineering Faculty of Los Mochis of the Autonomous University of Sinaloa, who have knowledge and experience in the use of computer systems, which makes them appropriate for the study[25].

The activity that was prepared with the LSDS to run the non-functional and functional test set consisted of the following steps: 1) logging into the software; 2) answering the FSLSM questionnaire; 3) reviewing the individual results in the LS provided by the system. With the above, a moderated face-to-face test was conducted, with each session lasting about 15 minutes.

The system usability scale (SUS) was used to perform non-functional testing [26]. For this purpose, a sample of 83 students followed the steps indicated above. For functional testing, two tests were carried out. First, a functional correctness test to validate the algorithm developed to implement the FSLSM [26]. Next, a beta testing, where a sample of 50 students were asked to perform the activities stated above and derived from this, the system calculated and displayed the results obtained from their individual LS [26].

3.2. TSRS evaluation

To test the TSRS subsystem, a non-probabilistic convenience sample was taken from the total population of professors of three of the careers of the Mochis School of Engineering of the Autonomous University of Sinaloa. From it, 11 professors were selected from the Software Engineering career, who have extensive knowledge and experience in the use of software systems and programming languages, 3 from Civil Engineering who teach in the Software Engineering career, and 5 from Geodesic Engineering who are not very familiar with this type of software.

The activity that was prepared and performed by the teachers in the system to execute the non-functional and functional test consisted of: 1) Entering the software; 2) Selecting the career and group to be consulted; 3) Reviewing the group result provided by the system regarding the teaching strategies. With the above, a moderated face-to-face test was performed, in which each session lasted about 15 minutes.

For non-functional testing SUS was also used [26]. To carry it out, the selected teachers followed the steps indicated above. For functional testing, two tests were also carried out. First, a functional correctness test to validate the algorithm developed to recommend TS [26]. Next, a beta testing, where the selected teachers were asked to perform the activities stated above and derived from this, the system showed the predominant LS found per individual or group and recommended the most appropriate TS [26].

4. RESULTS AND DISCUSSION

4.1. Results

4.1.1. LSDS evaluation results

According to the SUS, a measure above 70 points is considered adequate and the usability of the system will be better as it approaches 100 points [27]. Based on this, the LSDS is considered "good" when it reaches 71.72 SUS points. Functional correctness of the FLSSM algorithm were verified through the validation of its I/O according to several existing commercial tools and published works [9], [28]-[30]. In all cases, the results were correct. For the beta testing, the system calculated and displayed the results obtained from individual LS of the 50 students in the format presented in Figures 5 and 6. According to what they expressed, the execution flow was as expected and there were no relevant hiccups. Table 1 shows the trend according to the number of students and the percentage in which each style predominates.

Table 1. Results of the Felder and Silverman test by group

Students	Active	Reflective	Detection	Intuitive	Visual	Verbal	Sequential	Global
50	39 (78%)	11 (22%)	38 (76%)	12 (24%)	42 (84%)	8 (16%)	35 (70%)	15 (30%)

4.1.2. TSRS evaluation results

As a result of SUS evaluation and in accordance Bangor *et al.* [27], the TSRS is considered fairly good, reaching 98.9 SUS points. To test the functional correctness of the algorithm that was developed to recommend TS were correct, the results obtained for different inputs were verified against various published works [16], [17], [29]. In all cases, the results were correct. For beta testing, the system calculated and displayed the results obtained for the predominant LS found per individual or group and recommended the most appropriate TS as shown in Figures 8 and 9 according to the expected execution flow and without hiccups.

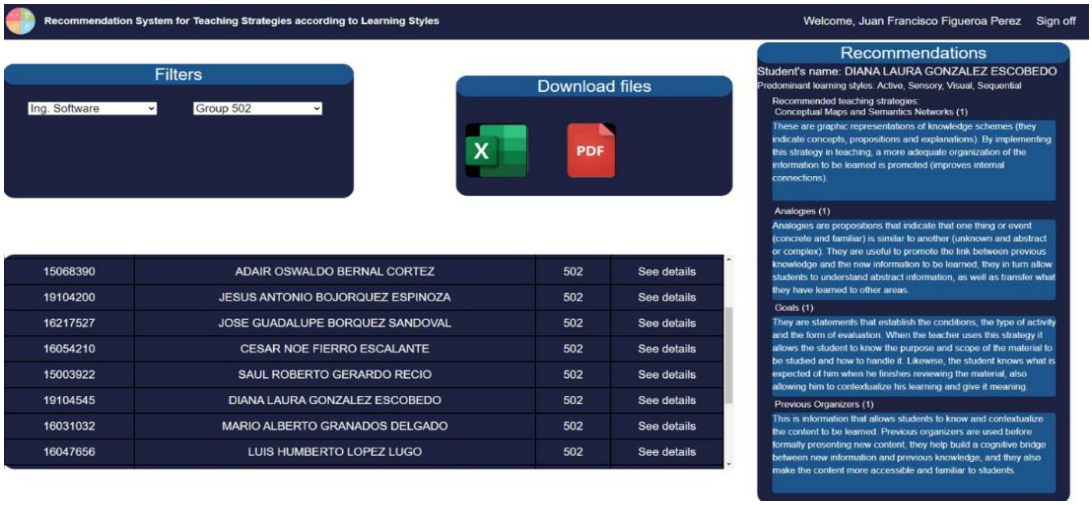

Figure 8. Recommended TS for a specific student based on his/her LS

Figure 9. TS recommended for a given group of learners according to their predominant LS

4.2. Discussion

The RSTSLS presented in this paper is intended to serve as a support tool for the teaching-learning process for teachers, helping them select the most appropriate TS to use according to the LS that predominate in an individual student or group, taking advantage of their individual potentials and capabilities and focusing their efforts on getting the greatest possible benefit from these. The software allows to identify the LS of the students according to a well-accredited model in the literature such as the FSLSM, and the TS recommendation is based on what has been established by recognized authors in the field, which makes it robust and reliable. The system proposal is innovative because after a systematic literature review, no software has been found that performs in a unified way the detection of LS in students with the recommendation of TS to teachers. The unification of these tasks in a single tool may promote good acceptance by users, since this generates an important differential with respect to other offers currently available in the market, which, although they perform these tasks, do it separately and not in a joint and integrated way.

5. CONCLUSION

Knowing students' LS is very important for teachers since this can allow them to adapt their TS to their characteristics, thus contributing to improving the teaching-learning process. This paper describes the development, characteristics, operation and an example of use of a new RSTSLS which computationally implements Felder and Silverman's LS model.

The document first presents the development decisions such as the selected architecture, details of its implementation and the software functionalities. Then, an illustrative example of the use of the same is presented. After that, the different functional and non-functional tests that were applied to the software are described, which were satisfactory.

Derived from the results of the applied tests, it is concluded that the proposed software can be useful as a support tool for teachers, allowing them to know the LS of their students and thus be able to adapt their TS to the characteristics they present, taking advantage of their potential and individual capabilities. The system proposal is innovative because, after a systematic literature review, no software has been found that performs in a unified way the detection of LS in students with the recommendation of TS to teachers. The unification of these tasks in a single tool can promote good acceptance by users, since this generates an important differential with respect to other offers currently available in the market, which, although they perform these tasks, do it separately and not in a joint and integrated way.

Finally, the results obtained by the software will allow us to know the individual LS of the students in a group and thus be able to classify them accordingly. This can serve as a basis for future lines of research, including analyzing to what extent the use of software can help improve the academic results obtained and exploring different ways of classifying students according to their LS to recommend the most appropriate TS for preparing regular classes, special courses, and extraordinary exams.

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AUTHOR CONTRIBUTIONS STATEMENT

Name of Author	C	M	So	Va	Fo	I	R	D	O	E	Vi	Su	P	Fu
Juan Francisco Figueroa-Pérez	✓	✓	✓	✓	✓	✓	✓		✓		✓	✓	✓	
Manuel Rodríguez-Guerrero	✓		✓			✓	✓	✓		✓	✓			
Alan Ramírez-Noriega	✓	✓		✓	✓					✓				
Yobani Martínez-Ramírez	✓									✓				

C : **C**onceptualization
M : **M**ethodology
So : **So**ftware
Va : **Va**lidation
Fo : **Fo**rmal analysis
I : **I**nvestigation
R : **R**esources
D : **D**ata Curation
O : Writing - **O**riginal Draft
E : Writing - Review & **E**diting
Vi : **Vi**sualization
Su : **Su**pervision
P : **P**roject administration
Fu : **Fu**nding acquisition

CONFLICT OF INTEREST STATEMENT

Authors state no conflict of interest.

DATA AVAILABILITY

The data that support the findings of this study are available from the corresponding author, JFFP, upon reasonable request.

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