Design of an Adaptive Educational Application to Generate Customized Tests Based on Ontology

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Danilo Pástor (✉), Gloria Arcos-Medina, Vanessa Bonito,
Jaime Cepeda
Escuela Superior Politécnica de Chimborazo, Riobamba, Ecuador
dpastor@espoch.edu.ec

Abstract—The personalization of certain teaching processes produces improved learning results. In the assessment of learning, there is a need to personalize the test items according to the learning styles of the students. This paper proposes the design of an adaptive application that generates personalized tests according to the students' learning styles. To facilitate the design of the proposed application, an ontology for creating personalized tests was designed based on the use of learning styles by means of applying the Methontology methodology. This ontology has a hierarchy of 3 levels, 9 first-level classes, 12 second-level subclasses, and 10 third-level subclasses. The application was developed using the Primefaces framework and the Jena library to manage the ontology. At the end of the development stage, the usability of the application created was measured using the heuristic evaluation method based on the ten principles of Jackob Nielsen. The results obtained indicate that the application complies with the aforementioned principles, earning a 94% usability rating. Consequently, it can be deemed a useful application for end-users.

Keywords—Adaptive application, ontology, learning styles, Bloom Taxonomy

1 Introduction

The use of virtual learning systems has become indispensable in educational institutions. Most of these institutions offer virtual platforms for their students to attend virtual classrooms. The teaching process of these systems is characterized by selecting educational material that is then transmitted by the teacher to all of the students present. In other words, the educational content is fixed and designed to support all of the learners as a group to meet their collective learning needs [1]. Consequently, students do not have personalized alternatives and are unable to choose the educational resources and activities according to their preference or learning style, given that the instructor does not design the material for individuals, but rather, does so in a generalized way.

New approaches to educational applications that are emerging rapidly, due to the utilization of artificial intelligence. Among the most prominent to have emerged are personalized learning services, which provide adaptable educational solutions to improve the teaching process for individual students [2]. Personalization is a process that provides a student with the best alternatives to access, retrieve, and store information based on various characteristics of the user [3]. A major benefit of this system is that a single student can have access to a variety of learning materials, in other words, the learning content depends on the student's personal preferences and learning style.

There are studies on the adaptation of educational content linked to the learning styles of each student [4], [5]. However, no literature has been found that focuses on the creation of automatically generated tests using ontologies that employ Bloom's taxonomy. The test creation process is a task that requires a lot of effort and, at times, the way in which the questions are posed is not clearly understood by each student. Therefore, to fulfil educational objectives, the need arises to customize the questions according to the learning styles of the students. In this context, a need has been created on the part of teachers for them to be able to personalize the production of their tests, making use of the learning styles of each student individually.

Several research works have investigated adaptive systems in education. One of them presents a proposal based on an ontology to develop a personalized E-learning system that generates adaptive content based on the skills, learning style, level of knowledge, and student preferences [6]. Another work proposes in a general way a set of ontologies that model the educational domain and learning styles but focus only on learning objectives and the environment of a class and do not address the development of an application to fulfil those aims [7]. Additionally, there is a study that proposes an intelligent framework using an ontology to help in the learning process, however, it focuses only on the components of the learning process and does not include the aspect of evaluating students [3]. We can acknowledge other evaluation works such as [8], [9], which permit the automated collection of complementary information and allow other types of analysis to be carried out. Nevertheless, they do not use current technologies such as ontologies.

The main objective of this work was to develop an adaptive evaluation application using ontology. The application allows a teacher to evaluate students according to their respective learning styles. The "Methontology" methodology was used to create an ontology from the perspective of various domains: the teacher, the student, Kolb learning styles, and personalized tests.

This paper is organized as follows. The second section describes the conceptual framework. The third section describes the methodology that was used to develop the ontology and the adaptive assessment application. The fourth section assesses the results obtained regarding the usability of the application using the heuristic evaluation method under the ten principles of Jackob Nielsen. Finally, the fifth section details some conclusions procured from the research.

2 Conceptual Framework

2.1 Customized learning

The current teaching-learning process converges at a personalized education where the needs of each individual student are met. This process is evaluated to ensure that a unique learning experience occurs for each student [10].

Personalized learning optimizes the educational environment by adjusting to the student's diverse needs and abilities and provides an individualized learning experience through student-led learning and active learning. There are many difficulties in meeting those learning objectives in an environment that includes many students with different individual variations. The need for personalized learning is currently increasing [11].

As a consequence of this approach, new strategies are required to map out the information in order to support the personalization of evaluations according to the profile of each student. There are studies regarding the personalization of learning using Information and Communication Technology ICT and Learning Styles LS, as was the case at the University of La Rioja (UR). The university carried out a project where, by taking advantage of mobile technology and collaborative tools, the traditional teaching model was modified. A similar experience was also carried out at the University of Murcia (UMA), where the students themselves were the creators of the didactic content [12].

These studies have demonstrated the advantages of personalizing learning produced in conjunction with ICT. For this to materialize, it is essential to understand the learning styles of students and recognize the key role they play in learning development [13]. In this unique study, the experiential learning theory [14], Bloom's taxonomy [15], and ontology [16] are adopted to generate personalized tests.

2.2 Kolb's learning model: Learning styles

Learning is a series of biological and psychological processes that occur in the cerebral cortex [17] that integrate the behaviour, feelings, thoughts, and perceptions of the student. The process is profoundly complex and has been studied by several researchers. One of those researchers is David A. Kolb, a psychologist and educational theorist. Kolb established the experiential learning theory and identified experience as the central point of the learning process as it occurs in 4 stages: Concrete Experience (CE), Reflective Observation (RO), Abstract Conceptualization (AC), and Active Experimentation (AE). This model is presented in Fig. 1. The process can begin in any of the stages and is considered as a repetitive cycle where what has been learned is reaffirmed and new knowledge is acquired [18].

Each student progresses through the learning cycle in a different way. According to Kolb, there are 3 factors that determine the student's approach to learning. They are genetics, lived experiences, and environmental demands. Consequently, each student has their own learning style, defined as the combination of cognitive, affective, and physiological characteristics that indicate the way in which the student perceives the learning experience. Within the experiential learning model, the 4 learning styles are defined as Accommodator, Converger, Assimilator, and Diverger [19], [20].

Kolb proposed a means to determine the learning style of each individual student. The tool is known as the Learning Style Inventory (LSI), which consists of a questionnaire of 12 questions each which must be scored from 1 to 4 without these values being repeated or omitted [21].

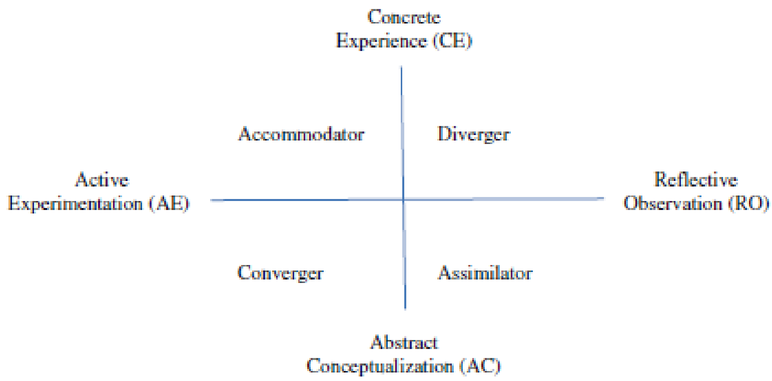

Fig. 1. Kolb's Experiential Learning Model [22]

2.3 Bloom's taxonomy

Bloom's taxonomy is used by teachers to measure knowledge. It enables structuring the tasks and assessment strategies according to the established teaching objectives [23]. Since its publication in 1956 by educational psychologist Benjamin Bloom, the taxonomy has had two revisions. The last revision was published in 2008 by Churches. It specialized in digital environments, thus covering the needs of ICT. The taxonomy has the following learning levels: Remember, Understand, Apply, Analyse, Evaluate, and Create [24].

2.4 Ontologies

An ontology is the formal representation of an area of knowledge that allows for inferences and the generation and exchange of knowledge between computers [25]. Due to the nature of the ontologies, the data of the learning styles of the students and the teaching objectives can be represented as a true knowledge space, thus facilitating the adaptation of the educational process to each student, which makes ontology a powerful tool for use in the educational field. Several ontologies have been proposed for education to describe the content of documents used as educational resources, the interaction between students during collaborative learning tasks, the semantics related to the objectives of learning, and finally, the inherent semantics in languages oriented to the design of learning [26].

Examples include a study called the Ontologies of the student model and the domain model in adaptive and collaborative learning systems [7], where the creation of two ontologies is recognized, in which the first is the representation of the student model performed by outlining the characteristics that define their academic profile and the other is the representation of the learning domain model, to procure new knowledge and content from web resources. There is also the study Exploration of Learning Service Discovery Algorithm based on Ontology [27], which focuses on the search for learning services in networks based on a UDDI algorithm with an OWL-S algorithm as an ontology.

3 Methodology

In order to meet the objectives of this research, the process was divided into three stages:

1) Development of an ontology in several domains: teacher, student, Kolb's learning styles, and personalized tests applying Methontology
2) Development of an adaptive application that allows teachers to evaluate students according to their respective learning styles
3) Evaluation of the usability of the application.

3.1 Ontology development methodology

For the development of the ontology, Methontology was appropriated. This methodology was created for the construction of ontologies in the Foundation of Intelligent Physical Agents (FIPA). It is a well-structured methodology used to build ontologies from scratch. The methodology includes a set of activities, techniques to implement each one, and deliverables to be produced after the execution of such activities using its attached techniques [28]. Methontology has the following development stages: specification, conceptualization, formalization, implementation, and maintenance [29].

In the Specification phase, the purpose of creating the ontology was determined, namely, generating tests based on the learning style of a student. The following domains were established: Teacher, Student, Kolb's learning model, and Customized tests.

In the Conceptualization phase, a semi-formal notion of the established domains was conceived. First, the concepts of the identified domains were identified, and a glossary of terms was created. Then, the classes with their respective hierarchy and properties were identified. Finally, the binary relationships between classes were specified to represent their interaction within the domains.

In the Formalization phase, a semi-computable model was built on the semi-formal model by using the Cognitum Fluent Editor tool that uses English as a controlled natural language, supported by Predictive Editor which prevents the introduction of any phrase that is grammatically or morphologically incorrect [30].

In the Implementation phase, the semi-computable model was translated into OWL-DL ontological language [31], employing Fluent Editor to comply with the principal W3C standards. Using the Export to OWL option of the ontologies editor, the semi-computable model was implemented creating a .owl file type, resulting in an ontology with a hierarchy of 3 levels: 9 first-level classes, 12 second-level subclasses, and 10 third-level subclasses. The ontology created has a total of 31 classes, 58 properties, and 39 binary relations between the classes, of which 14 are inverse functional and 25 are functional. In Fig. 2, the structure of the created ontology can be observed.

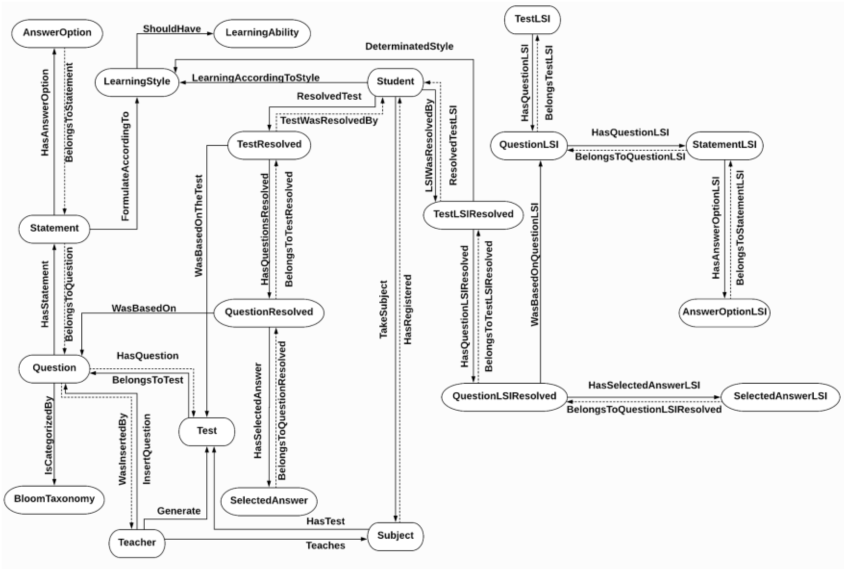

Fig. 2. Description of the structure of the ontology.

3.2 Development of the adaptive assessment application

For the development of the web application, the Scrum methodology was used. That methodology applies principles of the process control theory for software development, resulting in a productive, flexible, and adaptable approach to necessary changes [32]. It manages iterations of deliverables called sprints. In each sprint, there are three phases: the pre-game, where planning is carried out, development, where the planned tasks are developed, and the post-game, where the deliverable is produced and feedback is given on the developed work [33].

Furthermore, Methontology was used for the development of the ontology during the first two development sprints. Using Scrum, the application was developed during 16 sprints where 6 technical stories, 27 user stories, 137 engineering tasks, and 94 successful acceptance tests were generated.

Application architecture: The main component of the application architecture design is the ontology developed for the generation of customized tests. In Fig. 3, you can see the application architecture scheme and the interaction of its components.

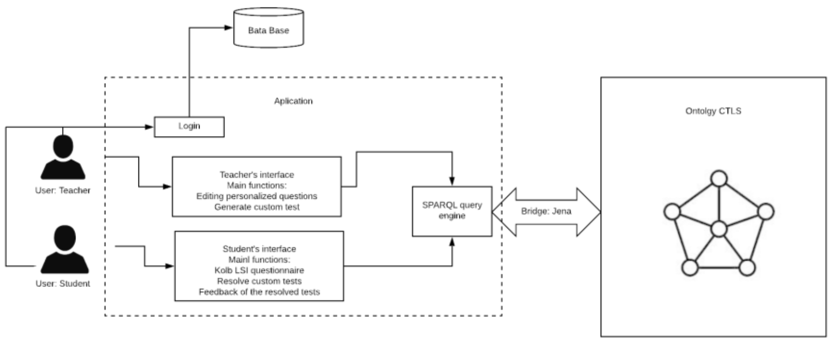

Fig. 3. Adaptive application architecture

The teacher, through the interface offered by the application, enters the questions that will be personalized according to the 4 learning styles of Kolb. The questions are classified by subject and stored in the ontology. On the student's end, the student completes the Learning Styles Inventory (LSI) questionnaire indicating to the ontology information about their aptitudes and abilities. The results of the questionnaire will determine the student's learning style. Subsequently, the data is stored in the ontology.

After the student evaluation, the SPARQL query engine performs a process within the ontology to determine the student's learning style and then, based on the result, obtain the appropriate customized test for the student. In this way, the application creates a personalized evaluation process.

Application development: The main component of the application is the constructed ontology called LSCT (Learning Style based Custom Tests) that covers different domains: Teacher, Student, Kolb's learning model, and Customized tests, as explained in section 3.1. In Fig. 4, the Teacher domain is represented, where the teacher has been conceptualized as a class within the ontology with its own respective profile. The way in which the teacher relates in the academic environment with the student and the subject in the curriculum has also been defined, recognizing the teacher as the one who supervises the learning process. In the evaluation part, the teacher edits the question that is saved within the ontology, so that when the teacher generates a test, the ontology is able to customize the test, taking into account the student's learning styles.

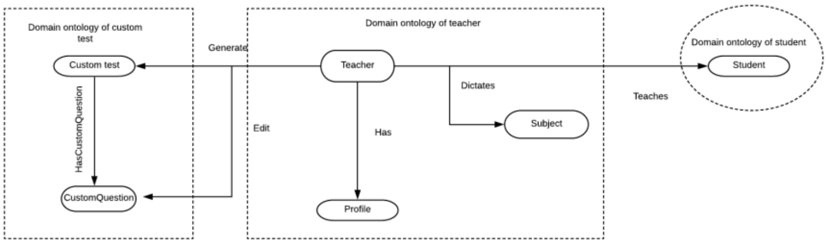

Fig. 4. Teacher domain within the ontology

In Fig. 5, the student domain within the ontology is expressed. Initially, the student's learning style is determined according to the LSI previously completed by the student. The student takes various courses and learns according to the learning style indicated by the aptitudes and learning abilities of the student, a key part in the process of personalizing the tests. In turn, the structure is defined by the stored tests concluded by the student themselves. They are part of the feedback used to improve the student's learning progress.

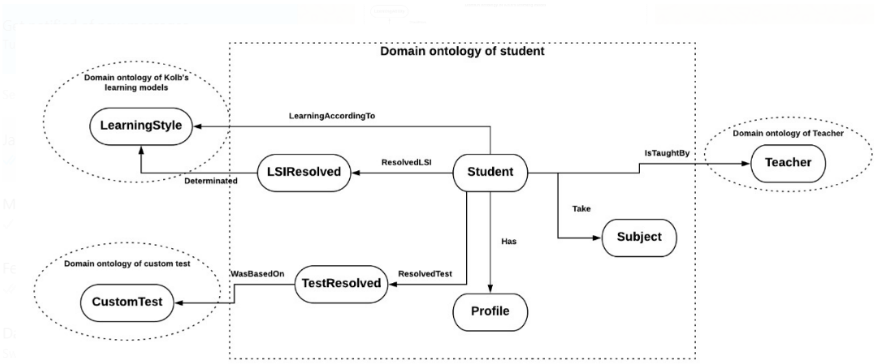

Fig. 5. Student domain within the ontology

For the representation of the learning styles model, a conceptualization of David A. Kolb's theory of learning styles was made, which is expressed in Fig. 6. In the ontology, we have the Kolb's Learning Model class that utilizes Kolb's four learning styles, where each style possesses distinctive skills and aptitudes for learning. The LSI questionnaire has also been incorporated and represented in the ontology.

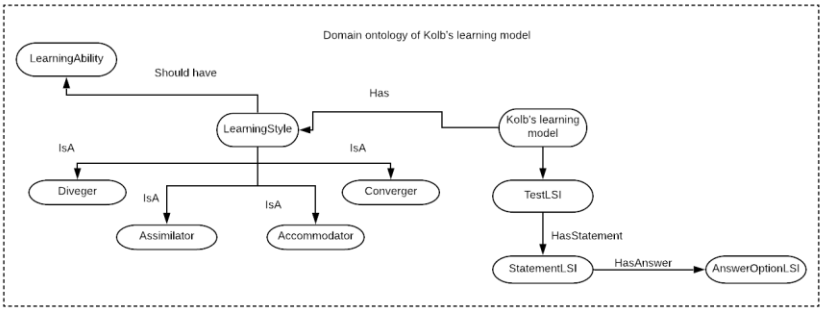

Fig. 6. Kolb's learning model domain within the ontology

To represent the domain of the customized test, the custom question class was created and was categorized according to Bloom's taxonomy and adapted to Kolb's learning styles, as shown in Fig. 7. The entities that were created from this class form a bank of questions stored in the same ontology from which the customized test is generated for each student according to their learning style.

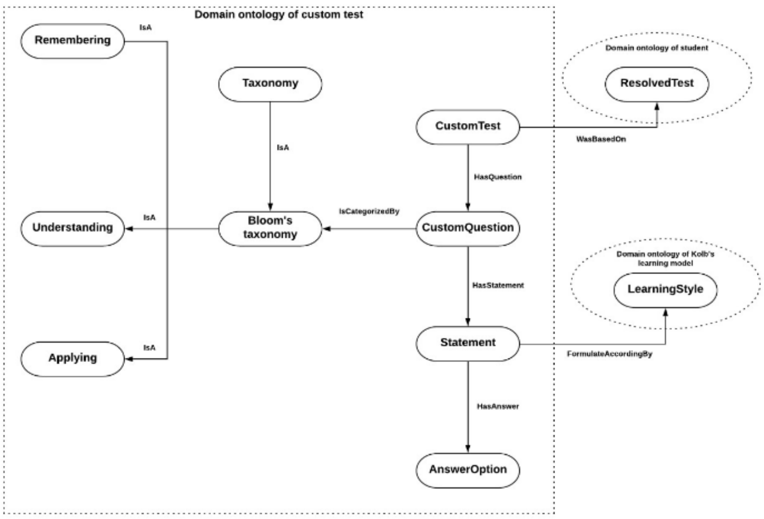

Fig. 7. Customized Test domain within the ontology

The previously described domains interact with each other in the LSCT ontology to obtain the customized test by using SPARQL query processes. In this process, the student completes an LSI based on the LSI of the domain of Kolb's learning model, thereby determining a Learning Style. For their part, the teacher teaches the course to the student and edits the Customized questions. Then, after evaluating the information provided by the learning ontology through sentences containing queries, SPARQL selects a set of personalized questions that will make up the test. The following is the

SPARQL query that enables the creation of the customized test for a student with a divergent learning style.

```
PREFIX pbea: <http://webapp.espoch.edu.ec/pbea/PBEA.owl#>
     SELECT DISTINCT ?Test ?Id ?Tittle ?Description ?Score ?Date ?Num-
     berQuestions
   ?Resolution Time ?Cycle ?Question ?Bloom ?Statement ?TextE ?Option ?Tex-
to ?Type
      WHERE {
          ?Test pbea:IdTest ?Id.
          ?Test pbea:TitleTest ?Tittle.
          ?Test pbea:DescriptionTest  ?Description.
          ?Test pbea:TotalScore  ?Score.
          ?Test pbea:TestGenerationDate  ?Date.
          ?Test pbea:NumberQuestion  ?NumberQuestions.
          ?Test pbea:TestTime  ?ResolutionTime.
          ?Test pbea:StateTest  ?StateP.
          ?Test pbea:CycleTest  ?Cycle.
          ?Test pbea:HasQuestions ?Question.
          ?Question pbea:IsCategorizedBy ?TaxBloom.
          ?TaxBloom pbea:TaxonomyLevel ?Bloom.
          ?Question pbea:HasStatement ?Statement.
          ?Statement pbea:StatementText ?TextE.
          ?Statement pbea:FormulatedAccordingTo ?EstiloA.
          ?Statement pbea:HasAnswerOption ?Option.
          ?Option pbea:OptionAnswerText ?TextO.
          ?Option pbea:OptionAnswerType ?Type.
          ?Option pbea:StateAnswerOption ?StateO.
          FILTER (?Test = pbea:Test1 && ?StateO=1 && ?EstadoP=1 && ?Esti-
loA=pbea:Diveger)
      } ORDER BY ?Statement ?Option
```

Fig. 8. Divergent learning style result from Test 1.

Fig. 8 shows a query in which the result is refined by applying the FILTER command. In this example, Test 1 is obtained for the Divergent learning style. By applying this data, students at the time of taking the test will have personalized questions chosen according to their learning style. When the test is finished, it will be automatically corrected and graded, offering immediate feedback to the student.

The syllogistic expressed above is reflected in the application's user interface. When the student completes Kolb's LSI, the result is the interface shown in Fig. 9, where the learning style with its characteristics is presented.

Fig. 9. Student's LSI results Interface

The teacher is able to access the customized test interface that is presented in Fig. 10, where the subject of the test, the questions, and their response options for each question posed according to each learning style of the model by Kolb may be found.

Fig. 10. Customized test interface

The ontology, together with the SPARQL search engine, is responsible for providing the software in the application that is able to produce customized tests. The complete process of creating the test according to the learning style is unapparent to the student, who will only notice that the evaluation process is made according to their learning aptitudes, allowing students to see continued improvements and achievements made throughout the learning process.

3.3 Methodology to evaluate the usability of the application

To measure the level of usability of the application, the heuristic evaluation (HE) method was used. This method consists of a group of expert evaluators examining the application by assuming the role of users to confirm that it complies with a set of previously established heuristic principles [34]. The objective of the evaluation was to measure the usability of the application's user interface, assess the required learning curve, and measure the usability for certain users in specific contexts [35]. In this effort, the heuristic principles of Jackob Nielsen were used to evaluate usability [36]:

1. Visibility of system status
2. Match between the system and the real world
3. User control and freedom
4. Consistency and standards
5. Error prevention
6. Recognition rather than recall
7. Flexibility and efficiency of use
8. Aesthetic and minimalistic design
9. Help users recognize, diagnose, and recover from errors
10. Help and documentation.

Each usability problem found was filtered according to frequency parameters, i.e., the rate of occurrence of the problem, the severity of which the problem affects the ease of use once it occurs, and the criticality, the impact that the problem has on the user experience during using of the application. This last parameter is calculated by combining the severity and frequency values.

For the selection of the evaluators, the Nielsen and Launder criterion was followed, which indicates that, in order to carry out a heuristic evaluation, 3 to 5 evaluators are sufficient for the detection of errors [34]. Three evaluators who met the profile of usability experts and potential users were chosen. The evaluators were professors from Ecuadorian universities who specialize in the area of web usability and who have extensive experience in the educational field, management of virtual education platforms, and software development.

The process for evaluating the usability of the web application was as follows:

1. Each evaluator reviewed the application in individual sessions lasting one hour where they determined the usability of the application according to Nielsen heuristic principles
2. A heuristic evaluation template was filled out for each of the problems found
3. Quantitative values were assigned to the problems in terms of severity and frequency, and the criticality value was calculated
4. An analysis of the problems and the scores obtained were examined to determine the usability of the application.

4 Results

After the usability evaluations employing the heuristic method were performed, 26 problems were found, which were then quantified in severity and frequency and given a value on a scale from 0 to 4. The significance of each evaluation is based on [34] and is explained in Table 1.

Table 1. Applied values

Category	Value	Description
Severity	0	Not considered a usability problem
	1	Cosmetic problem
	2	Minor Problem
	3	Major Problem
	4	Catastrophic Problem
Frequency	0	Problem with an occurrence rate of <1%
	1	Problem with an occurrence rate of 1-10%
	2	Problem with an occurrence rate of 11-50%
	3	Problem with an occurrence rate of 51-89%
	4	Problem with an occurrence rate of >90%
Criticality	0	No criticality rating
	1 - 3	Low criticality
	4	Medium criticality
	>4	High criticality

All of the problems identified by the evaluators and their respective evaluations were consolidated into a single list, where the average of the previously explained qualifications was calculated (see Table 2) and where the problem is identified and described, and its average severity (S), frequency (F) and criticality (C) were calculated.

Table 2. Applied values

ID	Description	Nielsen Principle	Averages		
			S	***F***	***C***
P1	Status Label answer option is confusing.	Recognition rather than recall	1.333	2	3.333
P2	Description Label in question list is confusing.	Match between the system and the real world	1.333	1.333	2.667
P3	The title of the list of questions by subject is unclear.	Match between the system and the real world	1	1.667	2.667
P4	The subject to which the test belongs in the list of pending tests is not indicated.	Match between the system and the real-world Recognition rather than recall	1	1.333	2.333
P5	*Question not answered* message disappears too quickly.	Error prevention	2	1.667	3.667
P6	Home screen transitions are overly fast.	Aesthetic and minimalistic design	1	2.667	3.667
P7	Startup message *How to Proceed?* is not clear.	Aesthetic and minimalistic design	1.333	1.667	3

ID	Description	Nielsen Principle	Averages		
			S	***F***	***C***
P8	Image size distracts from home screen content.	Aesthetic and minimalistic design	1	1.667	2.667
P9	*My data* screen is too minimalistic.	Aesthetic and minimalistic design	1	1.333	2.333
P10	Font is too small.	Aesthetic and minimalistic design	2.333	3.667	6
P11	*Statements* display is unclear.	Recognition rather than recall	2	2	4
P12	Very intense blue color.	Aesthetic and minimalistic design	1.333	2.667	4
P13	Unable to view learning style profiles when *Statements* appear or in quiz detail.	Recognition rather than recall	2	1.333	3.333
P14	There is no explanatory video of Kolb's model.	Help and documentation	2	1	3
P15	Deleted elements are unable to be restored.	User control and freedom	3	3	6
P16	Modifying personal data is not allowed.	User control and freedom	2	1.667	3.667
P17	In the list of students, whether the student has completed the LSI questionnaire or not is not indicated.	Recognition rather than recall	3	1.667	4.667
P18	It is difficult to find a student on the list of students.	Recognition rather than recall	3	1.667	4.667
P19	The contrasting colors of the buttons is distracting.	Aesthetic and minimalistic design	1	2.667	3.667
P20	*Modify question* message in the question list is unclear.	Match between the system and the real world	2	1.667	3.667
P21	It does not allow a search of previously entered topics.	Recognition rather than recall	2.333	2	4.333
P22	It is impossible to identify where in the application the user is working.	Recognition rather than recall	3	3.333	6.333
P23	Column headings in the question list are unclear.	Match between the system and the real world	2	1.333	3.333
P24	Ordering the list of questions according to the user's criteria is not permitted.	User control and freedom Flexibility and efficiency of use	2	1.667	3.667
P25	Column headings in the test list are unclear.	Match between the system and the real world	2	1.667	3.667
P26	The help is not contextualized for the process of entering statements and generating tests.	Recognition rather than recall Help and documentation	2.333	2.667	5

In the previous table, the averages can be clearly observed. The severity values are within a range of 1 to 3, in frequency, a range of 1 to 3.66, approaching 4, and in criticality, the range is from 3.667 to 6.

The results of the measurement of severity are presented in Fig. 11. As can be seen, from the total of 26 problems found, 85% of the errors corresponded to a level of cosmetic severity or less (Value = 1, Value = 2). The remaining 15% correspond to major usability problems in the application. That percentage corresponded to four problems:

1. Deleted elements are unable to be restored
2. In the list of students, whether the student had completed the LSI questionnaire or not is not indicated
3. It is difficult to find a student on the list of students
4. It is impossible for the user to identify where in the application the user is working.

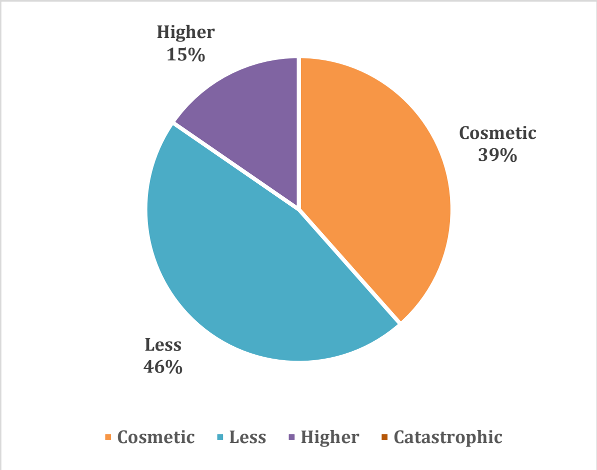

Fig. 11. Percentage of problems according to severity

The frequency parameter can be seen in Fig. 12. Of the 26 usability problems found, 8% have a high frequency of occurrence, while of the remaining 92%, the majority, corresponded to a low frequency of occurrence. This 8% was made up of two specific problems:

1. The font is too small
2. It is impossible to identify where in the application the user is working.

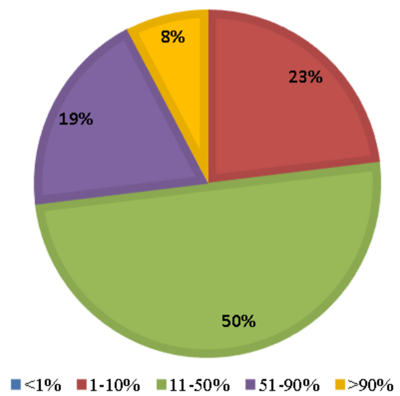

Fig. 12. Percentage of problems according to frequency

The severity and frequency are values that are combined to give an evaluative judgment called criticality. In order to identify the most critical problems for the usability of the application, a scale of 1 to 8 was established. Errors with a criticality average in the range of greater than 1 and less than 4 are regarded as not critical to usability. A range of greater than 4 and less than 5 are considered as medium criticality and any in the range greater than 5 are considered as high criticality and do not comply with Nielsen principles. In Fig. 13, it can be observed that the most prominent bar corresponds to low criticality problems, representing a total of 65% of the total errors, while high criticality problems only represent 12% with 3 usability errors. They are:

1. The font is too small
2. Deleted elements are unable to be restored
3. It is impossible to identify where in the application the user is working

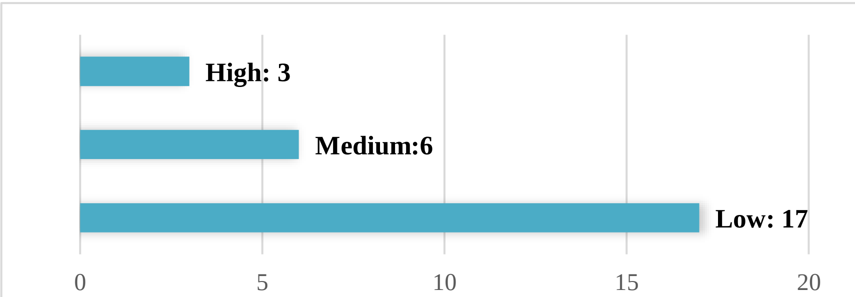

Fig. 13. Number of problems according to criticality

In conclusion, of the 26 problems found, only 3 are critical for the reason that they breach the third, sixth, and eighth heuristic principles. As a result of applying Nielsen’s 10 usability rules, 70% of the principles have been met. The most critical problems are explained in Table 3.

Table 3. Critical usability issues

Problem	Description	Applied Solution
The font is too small.	Violates the principle of aesthetic and minimalistic design with a criticality value of 6.	The font size was adjusted in the design of the user interface to facilitate a more legible reading of the content.
Deleted elements are unable to be restored.	Violates the principle of user control and freedom with a criticality value of 6.	A new section was added to give the user the option to reenable or permanently delete a question or test.
It is impossible to identify where in the application the user is working.	With a critical value of 6,333, it does not comply with the principle of recognition rather than recall.	To assist the user to navigate in the application, the breadcrumb technique was used, which bookmarks the user’s navigation path.

After applying the corrections explained in Table 3 to the application, its usability increased by 24%. This percentage is added to the 70% initially obtained in the heuristic evaluation, thereby obtaining a total of 94% usability, affirming the usability of the application.

5 Conclusion

The use of the experiential learning model, learning styles, and the Learning Styles Inventory (LSI) by David A. Kolb, combined with ontologies allow us to produce individualized learning for each individual student that serves as the basis for personalized online assessments.

Using Methontology, a conceptual model of the LSCT - Learning Style based Custom Tests ontology was defined with a total of 31 classes in a three-level hierarchy, 58 properties, and 39 binary relationships that cover the domain of Kolb's learning styles and their related skills, the LSI, and information from the personalized assessments.

The results obtained from the usability analysis of the application employing the heuristic evaluation method founded on the principles of Jackob Nielsen contributed to solving the critical problems found and improving the usability of the SysPBEA application, after which producing a percentage of 94% usability in accordance with the principles of Jackob Nielsen. Consequently, the developed tool can be considered usable.

Based on the adaptive application described, the learning styles model could be extended to encompass different projects outside that which Kolb had in mind when designing his learning styles. Also, it may be possible to analyse the possibility that the application could determine the need to change the question type based on the progress of the student throughout the test, with the aim of providing alternatives in other formats or different styles of questions. Additionally, a mechanism could be included that would allow for the generation of documents of the test results in a format that is able to be understood by machines, in order to publish said results in the form of open data.

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7 Authors

Danilo Pástor, **Gloria Arcos-Medina**, **Vanessa Bonito** & **Jaime Cepeda** Work for Escuela Superior Politécnica de Chimborazo, at Riobamba in Ecuador

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