

The suitable learning path for a learner

Adil HADDI

LIM@II (Laboratoire d'informatique)
Département d'informatique
FST Mohammedia
BP 146 Mohammedia 20650
Maroc
adil.haddi@gmail.com

Mohammed RAMDANI

LIM@II (Laboratoire d'informatique)
Département d'informatique
FST Mohammedia
BP 146 Mohammedia 20650
Maroc
moha@fstm.ac.ma

Mostafa BELLAFKIH

Institut National des Postes et
Télécommunications (INPT)
Rabat, Maroc
bellafkih@inpt.ac.ma

Abstract

The motivation behind this work is to realize the learning management system (LMS) where we take the automatic assessment of the learners, the documents and the trainers into account. We proceed to the automatic assessment of learners' responses to the exercises about the contained of learning units (training units). The responses assessment consists in calculating the degree of resemblance between the response models and learners' answers to the exercises suggested by the trainers. The responses models are stored in the XML data files. With this assessment, we can give a score corresponding to the degree of understanding the learning unit content by a learner. In order to evaluate the effectiveness of a learning unit and the pedagogic performance of a trainer, we used, in addition to the score, other parameters in the assessment such as the consultation time and the assessment time. These three parameters have been considered as the input of our automatic assessment system. The values of these parameters are captured and transferred to the assessment system which calculates a global score. The global score gives an idea about the level of understanding of the

learning unit by each learner. These scores are stored in a database in order to build pertinent indicators to evaluate, compare and classify learning units and trainers by using statistical techniques. Since there are several types of learning units, we apply the global scores to extract the learner's tendency in each learning unit type. We use this tendency in the hope to guide each learner in his/her learning path.

Keywords: answer assessment, understanding degree, ant colony, e-learning, document effectiveness, learner tendency, document conformity, learner guide.

1. Introduction

This work falls within the scope of realizing a distance Learning Management System [1] in which the assessment of each learner during his training is paramount importance.

In this article, we focus on assessing the learners' understanding of the learning units in order to assess the effectiveness of units and learners' tendencies to each type of unit, which we will use to switch the learners between the different learning units of a course.

In this article, we focus on the learner's understanding assessment in each learning unit in order to calculate two parameters which are the effectiveness of units and the tendencies of learners to each type of units. We will use these

parameters for switching the learners between the different learning units of a course.

Currently, there are only a few assessment units [9, 10, 13, 15, 17, 21, 23, and 26] in the learning systems. They take mainly into consideration the score obtained in a QCM without taking into account the consultation time and the assessment time. These assessment units don't give a clear idea about the understanding degree of a learning unit by the learner and about the degree of the effectiveness of the learning unit to transmit the knowledge to a learner. Now, several studies have been carried out about the adjustment of the learning units with the learner's profile [2, 3, 8, , 16, 18, and 25]. This requires the constitution of the learning units which are adapted to the learner's profile based on the course granularities and sequence models [5, 11, 12, and 22]. We have taken into consideration the difficulties to design learning units this way. To fill in this gap, we pretend to take learning units from various types and calculate their conformity to learners. To achieve this, we define the degree of the learning unit effectiveness and the degree of a learner's tendency as well as the relevance of the link between two units from two successive sections.

We try in this article to propose a method for switching the learners between the learning units based on the conformity of the learning units to learners and on the algorithm of ant colonies [14].

The classification of the documents by quality is very difficult because there are three views expressed by the trainer, the learner and the administrator. We develop a method based on the automatic learners' assessment. This assessment allows us to evaluate the effectiveness of document independently of the previous views. It also gives us an idea about the degree of the trainers' performance to develop documents.

This article is organized as follows: in Section 2, we evaluate the learners' responses (SQL case). In section 3, we calculate the global score of a learner in a learning unit. In section 4 will be devoted to the comparison of learners, documents according to their effectiveness to transmit knowledge and trainers according to their performance to develop documents. In

section 5, we propose a mechanism to switch learners between the learning units of a course.

2. Intelligent assessment of the answer

We applied the multicriteria assessment in a SQL course. In order to facilitate and structure the learning, we subdivided this course into several pedagogic learning units. As the understanding degree of a course by learners is based on their scores in various course's units. Therefore, in this article, we calculate only the understanding degree in each course unit. For example, we took the part of the SQL course concerning simple selection as pedagogic unit.

2.1. General treatment of answers in SQL

In order to give a score related to a learner's answer, we make a comparison between the answer proposed by this learner in an assessment exercise and the possible answer models related to this exercise (exact answers). These answer model elements are stored in the system in a structured way by using XML.

In order to oblige the learner to make considerable effort to resolve the assessment exercises, we carry out syntactic and lexical treatments of the answers proposed by the learners before their admission and comparison with the answer models. This allows the learners to avoid the typing errors (attribute names, tables or clauses are incorrect).

2.2. Syntactic analysis of answers

In our application, we treated the simplified selection requests about tables with attributes which are a string and/or an integer type. The general form of these requests is as follows:

```
SELECT Attribute1, Attribute2  
FROM Table1, Table2, Table3  
WHERE Filter
```

The *filter* can take one of the following forms:

- *Criteria*
- *Criteria* *operator_of_combination*
criteria

The *Criterion* (elementary condition) can take one of the following forms:

- *Attribute* *operator_of_comparison*
- *Attribute* *Attribute*
- *Attribute* *operator_of_comparison*
- *Constant* *Constant*

with:

- *operator_of_combination* $\in \{OR, AND, \dots\}$
- *operator_of_comparison* $\in \{=, >, <, like, \dots\}$
- *Constant* is a string (a suite of finite letters or numbers) bounded by double apostrophes or an integer.
- *Attribute* and *Table* are any suite of characters composed of letters, numbers or symbols $_$ and does not start with a number.

In practice, there are cases where the filters are constituted of several criteria combined by different operators of combination. In this case, we must be careful to the parentheses:

- The number of opening parentheses should be equal to the number of closing parenthesis.
- As the two expressions $(C_1 \wedge C_2) \vee C_3$ and $C_1 \wedge (C_2 \vee C_3)$ are different, it is not admitted to successively use two different combination operators without introducing parentheses to specify the priority of combination operators in any expression.

2.3. Answer treatment and assessment (SQL case)

2.3.1. Adaptation of filters

The answer models proposed by the trainer involve selection requests containing filters which have the following form:

$$Filtre = (C_{1,1} \wedge C_{1,2} \wedge \dots \wedge C_{1,n_1}) \vee (C_{2,1} \wedge C_{2,2} \wedge \dots \wedge C_{2,n_2}) \vee \dots \vee (C_{p,1} \wedge C_{p,2} \wedge \dots \wedge C_{p,n_p})$$

Thereafter, we call the filters with this form: standard filters. The filters introduced by the learners into their answers are not usually standard, but can be standardized by using the following logical distributions:

- $C_1 \wedge (C_2 \vee C_3) = (C_1 \wedge C_2) \vee (C_1 \wedge C_3)$

$$(C_2 \vee C_3) \wedge C_1 = (C_1 \wedge C_2) \vee (C_1 \wedge C_3)$$

We note that the filter normalization consists in looking in the filter for the following strings " \wedge (" or ") \wedge " and using the two previous equalities to standardize the filter. This allows us to standardize any filter.

We define, in the learning unit of SQL selection, the concept of standard filters. We ask the learners to write their request filter in the standardized form.

2.3.2. Answer assessment

A learner's answer is usually composed of three types: attribute, table and elementary condition. For this reason, the answer assessment must be based on these three types.

We extract three sets C_a , C_t and C_f from the learner's answer corresponding respectively to the three types of components: attribute, table and elementary condition.

We extract also from the answer models (exact answers) three sets C'_a , C'_t and C'_f corresponding respectively to the three types of components: attribute, table and elementary condition.

We calculate three elementary notes N_k ($k=a, t$ and f) corresponding respectively to the learner's success degree to extract the exact answer components (attribute, table and elementary condition). These notes are calculated as follows:

$$N_k = \frac{card(C_k \cap C'_k)}{card(C_k \cup C'_k)}$$

The N_k ($k=a, t$ and f) give an idea about the learner's success degree to extract the different components of the answer of the attribute type ($k=a$), table ($k=t$) and elementary condition ($k=f$).

Since the filter of a request consists of elementary conditions combined with combination operators, we propose to calculate a note corresponding to the combination of elementary conditions. This note corresponds to the learner's success degree in combining the

different elementary conditions which constitute the filter. It is easy to show that every filter:

- Can be transmitted in a standardized form
- Admits one and single standardized form

We force learners to give filters in the standard form, i.e. in the following form:

$$Filtre = (C_{1,1} \wedge C_{1,2} \wedge \dots \wedge C_{1,n_1}) \vee (C_{2,1} \wedge C_{2,2} \wedge \dots \wedge C_{2,n_2}) \vee \dots \vee (C_{p,1} \wedge C_{p,2} \wedge \dots \wedge C_{p,n_p})$$

In this case, we define the set F_c corresponding to the filter proposed by the learner as follow:

$$F_c = \left\{ \begin{array}{l} C_{1,1} \wedge C_{1,2} \wedge \dots \wedge C_{1,n_1}, C_{2,1} \wedge C_{2,2} \wedge \dots \wedge C_{2,n_2}, \dots, \\ C_{p,1} \wedge C_{p,2} \wedge \dots \wedge C_{p,n_p} \end{array} \right\}$$

The set F'_c corresponding to the filter proposed by the trainer is defined in the same way as F_c .

We calculate the combination note N_c corresponding to the learner's success degree to give the exact combination of filter elementary conditions by:

$$N_c = \frac{card(F_c \cap F'_c)}{card(F_c \cup F'_c)}$$

We use four notes N_k ($k = a, t, f$ and c) which are previously found to calculate the note N corresponding to the learner's success degree to give a correct (exact) answer. The note N is calculated by the aggregation of these four notes:

$$N = \sum_k \alpha_k N_k$$

with:

$$\sum_k \alpha_k = 1 \text{ and } 0 \leq \alpha_k \leq 1 \forall k \in \{a, t, f, c\}$$

The choice of weights α_k ($k = a, t, f$ and c) is fixed by the trainer.

2.4. Example of simple selection request assessment

We consider a simplified database version used in the management of school competitions. This database contains the following tables:

CANDIDATES (*ncand*, *name*): a candidate is identified by a unique number *ncand* and described by his/her *name*.

COMPETITIONS (*compname*, *price*): a competition is uniquely identified by its name *compname* and described by its price *price*.

REGISTERED (*ncand*, *compname*): a row in this table represents the fact that the candidate identified by his/her number *ncand* was registered in the competition identified by its name *compname*.

TESTS (*compname*, *testname*, *date*): a row in this table represents the fact that the competition identified by its name *compname* contains a test identified by its name *testname* which is described by its *date*.

SCHOOLS (*schooname*, *address*, *numplaces*, *compname*): a school is identified in a unique way by its name *schooname* and described by its address *address* and the place number *numplaces* that it offers. Recruitment at this school is done through a competition identified by its name *compname*.

RESULTS (*ncand*, *compname*, *testname*, *score*): a row in this table represents the fact that the candidate identified by its number *ncand* got a score *score* in the test designated by its name *testname* and the name of the competition *compname*.

The exact answer to the question: give the request SQL which will extract the names of the candidates registered in the competition associated to the school name "INPT", is:

```
SELECT name
FROM CANDIDATES, REGISTERED, SCHOOLS
WHERE CANDIDATES.ncand=REGISTERED.ncand
and REGISTERED.compname=SCHOOLS.compname
and schooname='INPT'
```

For the above exact answer, we obtain the following sets:

$$C'_a = \{name\}$$

$$C'_t = \{CANDIDATES, REGISTERED, SCHOOLS\}$$

$$C'_f = \{CANDIDATES.ncand=REGISTERED.ncand, REGISTERED.compname=SCHOOLS.compname, schooname='INPT'\}$$

$$F'_c = \{CANDIDATES.ncand=REGISTERED.ncand \text{ and } REGISTERED.compname=SCHOOLS.compname \text{ and } schooname='INPT'\}$$

We apply the method developed previously to assess the following answers given by learners:

- The first learner's answer is :

```
SELECT name, ncand
FROM CANDIDATES, REGISTERED
WHERE CANDIDATES.ncand=REGISTERED.ncand
and schooaname='INPT'
```

$C_a = \{name, ncand\}$
 $C_i = \{CANDIDATES, REGISTERED\}$
 $C_j = \{CANDIDATES.ncand=REGISTERED.ncand,$
 $schooaname = 'INPT'\}$
 $F_c = \{CANDIDATES.ncand=REGISTERED.ncand \text{ and}$
 $schooaname = 'INPT'\}$
 $N_a = 1/2$
 $N_i = 2/3$
 $N_j = 2/3$
 $N_c = 0$

with: $\alpha_a = \alpha_i = \alpha_j = \alpha_c = 1/4$ we obtain $N = 0,46$

- The second learner's answer is :

```
SELECT name
FROM CANDIDATES, REGISTERED, SCHOOLS
WHERE CANDIDATES.ncand=REGISTERED.ncand
and schooaname='INPT'
```

$C_a = \{name\}$
 $C_i = \{CANDIDATES, REGISTERED, SCHOOLS\}$
 $C_j = \{CANDIDATES.ncand=REGISTERED.ncand,$
 $schooaname = 'INPT'\}$
 $F_c = \{CANDIDATES.ncand=REGISTERED.ncand \text{ and}$
 $schooaname = 'INPT'\}$
 $N_a = 1$
 $N_i = 1$
 $N_j = 2/3$
 $N_c = 0$

with: $\alpha_a = \alpha_i = \alpha_j = \alpha_c = 1/4$ we obtain $N = 0,58$

- The third learner's answer is :

```
SELECT name, ncand
FROM CANDIDATES, REGISTERED, SCHOOLS
WHERE CANDIDATES.ncand=REGISTERED.ncand
and REGISTERED.compname=SCHOOLS.compname
and schooaname='INPT'
```

$C_a = \{name, ncand\}$
 $C_i = \{CANDIDATES, REGISTERED, SCHOOLS\}$
 $C_j = \{CANDIDATES.ncand=REGISTERED.ncand,$
 $REGISTERED.compname=SCHOOLS.compname,$
 $schooaname = 'INPT'\}$
 $F_c = \{CANDIDATES.ncand=REGISTERED.ncand \text{ and}$
 $REGISTERED.compname=SCHOOLS.compname$
 $\text{ and } schooaname = 'INPT'\}$
 $N_a = 1/2$
 $N_i = 1$
 $N_j = 1$
 $N_c = 1$

with: $\alpha_a = \alpha_i = \alpha_j = \alpha_c = 1/4$ we obtain $N = 0,875$.

We note that the score N defines correctly the resemblance degree between the exact answer and the learners' answers:

- If the learner's answer is closer to the exact answer, the note will be closer to 1.
- If the learner's answer is further from the exact answer, the note will be closer to 0.

3. The learner's global score in a learning unit

Classically, a learner's assessment is based on the note. This assessment does not take into account the consultation time which the learner made to read the learning unit nor the assessment time which the learner made to do the assessment exercise. Thus, the classical assessment does not allow us to classify and to compare the various entities involved in a LMS [7].

In order to evaluate the learning unit effectiveness and the trainer didactic performance, we used in the assessment, in addition to the note, other parameters such as the consultation time and the assessment time.

Every passage of a learner A_j through a learning unit U_i generates the values of the following parameters:

$T_{i,j}^c$: the consultation time that the learner A_j made to consult the learning unit U_i .

$T_{i,j}^e$: the assessment time that the learner A_j made to do an assessment exercise about the content of the unit U_i .

$N_{i,j}$: the note corresponding to the degree of understanding the content of the unit U_i by the learner A_j .

The three parameters described above are used as the input of the multicriteria and automatic assessment unit (fig.4.1) of our system LSSMA. The values of these three parameters have been captured and transferred to the multicriteria assessment unit by the system. This assessment unit transforms the above parameters into a single value, which is the global score $N_{i,j}^g$.

The assessment unit is a global function h of three input variables (parameters). This function must also respect the following properties:

- Increasing according to the variable corresponding to the global score $N_{i,j}$.
- Decreasing according to the variables corresponding to the consultation time and the assessment time.
- The values returned by this function should be in the interval $[0,1]$.

To construct the function h , we used two functions f and g :

- The function g having three input parameters which are the assessment parameters such as:

$$g : (N_{i,j}, T_{i,j}^e, T_{i,j}^c) \mapsto (N_{i,j}, \frac{N_{i,j}}{T_{i,j}^e}, \frac{N_{i,j}}{T_{i,j}^c})$$

- The function f agglomerate the three values returned by the function g . This function returns the global score given to the learner. In order to respect the properties of the function h described above, the function f must verify the following properties:

- $f(x,y,z) \in [0,1] \quad \forall (x,y,z) \in [0,1] \times \mathbb{R}^+ \times \mathbb{R}^+$
- f must be increasing according to all its variables

For example, we took the function f defined by:

$$f: [0,1] \times \mathbb{R}^+ \times \mathbb{R}^+ \rightarrow [0,1]$$

$$(x,y,z) \mapsto \alpha \times x + \beta \times \frac{y}{1+y} + \delta \times \frac{z}{1+z}$$

Where α, β, δ are the weights imposed by the trainer such as:

- $\alpha, \beta, \delta \in [0,1]$
- $\alpha + \beta + \delta = 1$

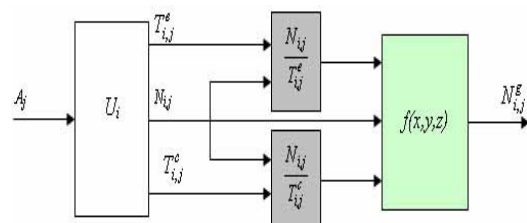


Fig.4.1: The learners' multicriteria and automatic assessment unit.

The global score $N_{i,j}^g$ summarized the comprehension degree of the learner A_j in the learning unit U_i . This will serve as a basis to compare and to classify the various entities participating in a learning management system (LMS).

4. The learners' switching between the learning units

There are the various document generation techniques. In fact we can propose to the learners the learning units from several types such as text, animation flash, audiovisual

The support of courses is diversified in our e-learning system. Each course is composed of several sections [6]. We introduced in each section some learning units (didactic learning units) from various types $(R_l)_{l=1,2,\dots}$.

We consider that the course is composed of m sections $(S_k)_{k=1 \dots m}$. Each section S_k contains n_k learning units $(U_{k,i})_{i=1..n_k}$.

Within the framework of the adaptation of courses to the learners, we seek in each section the unit, which is the most adapted to the learner's profile. The learner A who validated the unit $U_{k,i}$ in the section S_k may move towards another unit in section S_{k+1} according to its conformity to the learner A . Thus, each learner has his/her own path.

The course is modelled by a graph (fig.4.1) [20, 24] where each node represents a learning unit and each arc represents a link between two learning units in two successive sections S_k and S_{k+1} .

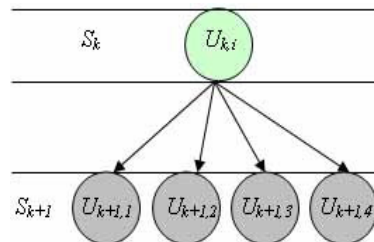


Fig.4.1: Reduced view of the graph of nodes and arcs ($n_{k+1}=4$)

4.1. The learners guide factors

4.1.1. Effectiveness of the didactic learning units

Each learning unit is characterized by its effectiveness to transmit the knowledge to learners. We calculate the effectiveness μ_i of the learning unit U_i by the average of the global scores obtained by all learners who consulted this unit:

$$\mu_i = \frac{\sum_{j \in S_i} N_{i,j}^g}{m_i}$$

Where S_i is the set of learners who have used the learning unit U_i , and m_i its cardinal.

4.1.2. The learners' tendency to a type of unit

We found that a learner may react differently from a type of unit to another. In fact, a learner's tendency to the types has been considered as his/her switching parameter. We calculate the tendency $\tau_{j,l}$ of a learner A_j to the type R_l by the average of global scores obtained by the learner A_j in all units which their type is R_l .

4.1.3. The pertinence of arcs

Each arc is characterized by its pertinence value. For example, the arc that links between the unit $U_{k,i}$ of section S_k and the unit $U_{k+1,j}$ of section S_{k+1} is characterized by the pertinence $P_{i,j}^k$. The pertinences of arcs which leave the section S_k units towards the section S_{k+1} units are represented by the matrix $(P_{i,j}^k)_{i=1..n_k, j=1..n_{k+1}}$. One of these arcs is first chosen by the trainer as an arc which is more pertinent than others (pertinence was initialized at 1). The arcs, whose pertinences are weak, are initialized to 0. The passage of the learner which validated the unit $U_{k,i}$ towards the unit $U_{k+1,j}$ change the pertinence value $P_{i,j}^k$ of the arc which connects these two units. If this learner had a global score N in the unit $U_{k+1,j}$, the pertinence would have a new value that is calculated by the following recurrence relationship:

$$P_{i,j}^k \leftarrow P_{i,j}^k + \frac{(N - P_{i,j}^k)}{(n_{i,j}^k + 1)}$$

Where $n_{i,j}^k$ is the number of learners who have consulted learning unit $U_{k,i}$ then $U_{k+1,j}$.

4.2. The learners switching based on ant colonies

The ant colony algorithm is an algorithm for finding optimal paths. This algorithm is based on the behaviour of real ants searching food: filing and tracking the pheromone seen in the ant colonies. The ant colonies are often seen as the distributed systems which can solve problems through the indirect communication: dynamic modification of environment.

With a simple decomposition of courses into sections and units, the ant colony algorithm could solve the problem of learners guide in their learning. The main mechanisms used in this algorithm is the propagation of information (the effectiveness of didactic learning units, the pertinence of the arcs and learners' tendency) accumulated by the system through the navigation of the learners between learning units of courses. This communication mechanism of information describes the functioning mode of ant colony. The learners switch (guide) problem is usually described by an objective. The objective of our switch mechanism is to guide a learner to the most conform unit.

4.2.1. The conformity of a learning unit to a learner

When a learner A_p validated a learning unit $U_{k,i}$ of the section S_k , it is appropriate to choose a learning unit among the section S_{k+1} units. This unit should be most suited to the learner A_p . The selection process is based on the ant colony algorithm and on four factors: the learner's A_p tendencies $(\tau_{p,l})_{l=1,2,\dots}$ to the types $(R_l)_{l=1,2,\dots}$, the section S_{k+1} units $(U_{k+1,j})_{j=1..n_{k+1}}$ effectiveness $(\mu_{k+1,j})_{j=1..n_{k+1}}$, the pertinences $(P_{i,j}^k)_{j=1..n_{k+1}}$ of the arcs that link the learning unit $U_{k,i}$ to units $(U_{k+1,j})_{j=1..n_{k+1}}$ respectively and the line $(H_{k+1,j}^p)_{j=1..n_{k+1}}$ of the historical factor

matrix H^p that contains information about the nodes (units) visited by the learner A_p . This matrix of m (number of sections) rows and $\max_{k=1..m} (n_k)$ columns is initialized to 1. The matrix elements corresponding to the learning units already visited by the learner A_p are set to 0.

The learning unit $U_{k+1,j}$ will be suitable (best conformity) for the learner A_p if:

- It has never been visited by the learner A_p . This means $(H_{k+1,j}^p = 1)$.
- It is more efficient.
- The learner A_p tendency $\tau_{p,\ell}$ to the type R_ℓ of this learning unit is the best. This means $\tau_{p,\ell} = \max_{q=1,2,\dots} (\tau_{p,q})$.
- The arc that links $U_{k,i}$ to $U_{k+1,j}$ is the most pertinent. This means $P_{ij}^k = \max_{q=1..n_{k+1}} (P_{i,q}^k)$.

We calculate the conformity of learning unit $U_{k+1,j}$ to the learner A_p by unifying all factors previously described:

$$C_k^p(i,j) = H_{k+1,j}^p * (\omega_\tau \tau_{p,l} + \omega_\mu \mu_{k+1,j} + \omega_p P_{ij}^k)$$

Where ω_τ , ω_μ and ω_p are respectively the weights of the tendency, effectiveness and pertinence.

4.2.2. The learners guide

We use conformity as the intensity of pheromones (used in the ant colonies) to guide the learners in their learning. When a learner A_p validate learning unit $U_{k,i}$ of the section S_k , the system will guide him/her towards the suitable learning unit of section S_{k+1} . If

$$C_k^p(i,j) = \max_{q=1..n_{k+1}} (C_k^p(i,q)) \text{ , the learning}$$

unit $U_{k,i}$ is the most suitable for the learner A_p and the system guides the learner A_p towards this learning unit.

When the learner A_p did not validate the learning unit $U_{k,i}$, he/she must take a step backward.

Note: The learner can move towards a learning unit which is not suggested. In this case, we are talking about non-guided navigation.

5. Conclusion and prospects

In this article, we presented a method for the assessment of the learners' responses (case SQL). Thus, our work on learners' multicriteria assessment in learning units enabled us not only to assess a learner's understanding, but also to evaluate the entities participating in an e-learning system. This gives us the most precise idea about the learner's capacity and tendency. It also helps us to define the learning unit effectiveness degree to transmit the knowledge.

We also proposed a mechanism using the conformity of the learning units to the learner's profile to guide a learner during his/her learning. e. We note that our switching system adapts to the learners and that its performance improves in the course of time.

In prospect, we intend to enrich this assessment units with exercises from the multiple levels of the difficulty and other parameters used in the calculation of the conformity of units to a learner's profile.

In this work, we treated the simple SQL requests, but we also plan to treat the complex requests.

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