The decisive learning skill for the scientific knowledge acquisition developed by artificial intelligence

Okacha Dyer\textsuperscript{1,2,*} and Naceur Achtaich\textsuperscript{2}

\textsuperscript{1}Training Center for Education Inspectors, Rabat, Morocco
\textsuperscript{2}Faculty of Sciences Ben M'Sik, University Hassan II, Casablanca, Morocco

Abstract. Several researchers in the field of education have taken an interest in the development of scientific skills. Their objective is to enable learners to have an attitude of reflection and behavior in the face of the different pedagogical situations that may arise. We are also interested in these scientific skills, namely $C_1$: Appropriate, $C_2$: Analyze and reason, $C_3$: Achieve, $C_4$: Validate and $C_5$: Communicate, we have characterized them by capacities whose objective is to evaluate them with interesting precision. We are interested in all these scientific skills but with significant weightings in order to realize a balanced, complete and effective overall assessment of scientific learning. In this work, we will also discover the most important scientific skill for the construction of Knowledge in a given scientific session, using artificial intelligence based on the decision tree by implementing a program in Python. Therefore, taking into consideration the one that leads to the birth of ideas and that allows to converge towards the objective, the teacher gives more importance to this skill and develops it by proposing different specific pedagogical situations. This learning approach allows the teacher to make the right decisions at the right time and it allows equity between the learners to acquire the different scientific skills according to their learning ability. Therefore it allows the learner an intrinsic motivation for the acquisition of scientific knowledge.

1 Introduction

Given the great technological and sociological revolution that has experienced the environment of the learner, scientific skills have undergone an interesting enrichment \cite{1–3}. Thus, trends in learning approaches have followed this growth and they have been adapted to the realization of these innovations. The works \cite{4–9} mentioned the different developments in the environment of the learning operation actors and in pedagogical innovation. This allows learners a motivating teaching using the different technological means, different teaching methodologies and different software and innovations computers. Artificial intelligence is present in a considerable manner in the learning operation \cite{10–12} to offer learners a structured education with enormous opportunities for the development of different scientific skills. This can offer a regularization of the learning process to allow students an equitable acquisition of different skills. The evaluation of the scientific knowledge acquisition takes several aspects by focusing on the dimensions that characterize these types of learning, namely

*\textcopyright{} The Authors, published by EDP Sciences. This is an open access article distributed under the terms of the Creative Commons Attribution License 4.0 (https://creativecommons.org/licenses/by/4.0/).
course questions, examples, application exercises and Deepening exercises [13]. Using an intelligent system, the teacher can dynamically assess science subjects based on structured regularization in order to make appropriate decisions at the right time to alleviate the learning difficulties encountered by their students. Recent research has used artificial intelligence by introducing the decision tree to predict the level of learners by focusing on the evaluation components of a science subject session [14], [15]. On the other hand, this latest research has focused on scientific learning skills by proposing an intelligent strategy to develop them, it characterizes these skills by capacities and it proposes an acquisition approach following an individualized procedure. In our research, we were interested in extending the work [16] which looked at the prediction of scientific skills by assuming that all these skills have the same weighting and impact on the overall acquisition of scientific subjects. In our study, we highlight the preponderant scientific competence for the acquisition of scientific knowledge. In fact the convergence towards the objective is done thanks to the competence which leads to the birth of the ideas in order to achieve the targeted objective. As a result, the teacher by taking an interest in this skill, he proposes pedagogical situations to improve it, which allows the students to conceive this attitude of judicious scientific reflection. This paper is organized as follows. In section 2, we give the research method used by offering the different scientific skills mentioned by characterizing them by capacities and providing the conception and modeling of the scientific skills assessment. In section 3, we apply the approach using artificial intelligence which is based on the decision tree. We interpret the results obtained, we specify the decisive scientific competence in the realization of the Scientific knowledge and we provide some educational means to develop it. Finally in section 4, we give a conclusion.

2 Research method

The acquisition of scientific skills is very important to equip learners with the attitudes of reflections and behavior that can occur through different interactions with their environments. Therefore, they can easily adapt with the circumstances of different other situations and interact with well-structured mechanisms and strategies. The teacher will thus be able to assess these skills and propose, if necessary, educational situations for remediation. Certainly, all scientific skills are important for the acquisition of scientific knowledge, however is there one that is preponderant in the acquisition of scientific knowledge? an original skill in the progression towards the intended objective and the learner must offer more effort to acquire it. What are the pedagogical means that can help the learner to develop this skill? To answer this problem, we begin to present the concepts of these scientific skills and the capacities that characterize them. We present our conception of the scientific subject skills evaluation through artificial intelligence based on the decision tree. Artificial intelligence can help us to detect this skill and can also prove its importance. By focusing on a specific weighting to fill the database, we detect the most important skill in predicting the acquisition of scientific knowledge. Therefore, we highlight all the criteria that promote this skill by giving it considerable importance.

2.1 Characterization of scientific skills

We first begin to present the five scientific skills, see Figure 1, which are widely spread in scientific knowledge, [12], [15], [16]. Then, we offer in the following, the concepts and capacities that characterize each scientific learning skill in order to facilitate their evaluations.

- $C_1$: Appropriate, it is the scientific skill which is characterized by, Identifying the data; Understand the data; Extract information; Organize information.
• $C_2$: Analyze and reason is the scientific skill that is characterized by, Finding relationships between data; Detect the objective to be achieved; Discover the lines of investigation; Suggest resolution methods.

• $C_3$: Achieve, it is the scientific competence which is characterized by, Execute a method of resolution; Progress according to a logic towards the objective; Apply other known information as needed; Experiment with a process.

• $C_4$: Validate, it is the scientific competence which is characterized by, Confirm; Criticize; Argue; substantiate.

• $C_5$: Communicate is the scientific competence which is characterized by, Reporting the result in a written text and/or in an oral discourse; Organize the written delivery; Write with a logical and understandable sequence.

2.2 Conception and modeling of competence assessment

The teacher must specify the existence degree of scientific skills to transmit a given concept and he must insist in his approach to highlighting these skills. During the evaluation, he proposes educational situations that evoke the different skills and he must know the degree of each existing skill in the proposed evaluation situations. The teacher offers a test at the end of the session comprising a set of questions and educational situations. He fills in an evaluation grid for scientific skills, based on the notation described in Table 1. As the teacher corrects the performance of each student, he prescribes his appreciation on a scoring grid, see Table 2. The system will then interpret the pre-entered results.

Table 1. Quantification of student performance according to the five-modal Likert scale

<table>
<thead>
<tr>
<th>Performance</th>
<th>Quantification</th>
</tr>
</thead>
<tbody>
<tr>
<td>Very well</td>
<td>4</td>
</tr>
<tr>
<td>Well</td>
<td>3</td>
</tr>
<tr>
<td>Medium</td>
<td>2</td>
</tr>
<tr>
<td>Insufficient</td>
<td>1</td>
</tr>
<tr>
<td>Very insufficient</td>
<td>0</td>
</tr>
</tbody>
</table>

Let $N$ be the number of students in a given class. For all $i$ in $[1, N]$, for all $j$ in $[1, 5]$, let $X_{i,j}$ be the student’s mark $E_i$ concerning the scientific competence $C_j$. $M_j$ is the class average
concerning the competence $C_j$.

$$\forall i \in [1, N], \forall j \in [1, 5], M_j = \frac{1}{N} \sum_{i=1}^{N} X_{i,j}$$ (1)

We have

$$\forall i \in [1, N], \forall j \in [1, 5], X_{i,j} \in \{0, 1, 2, 3, 4\} \text{ and } 0 \leq M_j \leq 4$$

**Table 2.** Students scoring grid according to scientific skills

<table>
<thead>
<tr>
<th>Student</th>
<th>$C_1$</th>
<th>$C_2$</th>
<th>$C_3$</th>
<th>$C_4$</th>
<th>$C_5$</th>
</tr>
</thead>
<tbody>
<tr>
<td>$E_i$</td>
<td>$X_{i,1}$</td>
<td>$X_{i,2}$</td>
<td>$X_{i,3}$</td>
<td>$X_{i,4}$</td>
<td>$X_{i,5}$</td>
</tr>
</tbody>
</table>

We model the operation of acquiring scientific skills as follows: Denote the set of all science skills by, $Comp = \{C_1, C_2, C_3, C_4, C_5\}$, where, $C_1$ : Appropriate, $C_2$ : Analyze and reason, $C_3$ : Achieve, $C_4$ : Validate, $C_5$ : Communicate. We are also interested in the whole of all scientific skills in order to achieve a balanced and complete teaching in scientific learning skills. For this, the influence of the weightings of scientific skills is of great importance for the overall acquisition of these skills. Thus, we present cases of weights which are well determined and we show their influences on the prediction of the global yield of scientific skills acquisition. Therefore we highlight the one that is essential in the progress of scientific acquisitions. Thus the teacher gives it more importance by improving it with adequate teaching situations. The purpose of the artificial intelligence used is not only to direct the teacher’s concerns to predict progress in scientific skills but also to help students who are struggling with these types of skills to improve them in a timely manner.

We consider the function $M$ which is the average evaluation of the session in scientific skills. Let $t_1, t_2, t_3, t_4, t_5$ be positive real numbers, let us set for all $i$ of $\{1, 2, 3, 4, 5\}$, $t_i$ the weighting of skill $C_i$, thus,

$$M(t_1, t_2, t_3, t_4, t_5) = \frac{t_1 M_1 + t_2 M_2 + t_3 M_3 + t_4 M_4 + t_5 M_5}{t_1 + t_2 + t_3 + t_4 + t_5}$$ (2)

To study the importance of the weighting on the acquisition of scientific skills, we evoke the following two cases:

- For weighting $P_1 : t_1 = t_2 = t_3 = t_4 = t_5$, $P_1$ corresponds to the same weighting coefficient for all the scientific skills, it has already been mentioned in the article [16].

$$M_{P_1} = M(t_1, t_2, t_3, t_4, t_5) = \frac{M_1 + M_2 + M_3 + M_4 + M_5}{5}$$ (3)

- For the weighting $P_2$, the choice of the weighting coefficients of these scientific skills are related to the importance in the resolution of the scientific situations. We assume that the importance of the scientific skills is as follows: $C_1$ and $C_5$ have the same degree of importance, $C_2$ and $C_4$ have the same degree of importance and $C_3$ has more importance than $C_2$ which is more important than $C_1$, so we take $t_1 = t_5 = 2$, $t_2 = t_4 = 3$ et $t_3 = 5$. Thus,

$$M_{P_2} = M(t_1, t_2, t_3, t_4, t_5) = \frac{2M_1 + 3M_2 + 5M_3 + 3M_4 + 2M_5}{15}$$ (4)

We present in Table 3, the global evaluation of the competence of scientific subjects and the recommendations given by the system at the end of a learning session. For all $k$ of $\{1, 2, \ldots\}$,
### Table 3. Global assessments of scientific skills

<table>
<thead>
<tr>
<th>Result magnitude</th>
<th>Correspondence</th>
<th>Assessment and recommendation</th>
<th>Level</th>
</tr>
</thead>
<tbody>
<tr>
<td>$M_{P_1} \in \left[\frac{16}{5}, 4\right]$</td>
<td>$E^{++}$</td>
<td>Scientific skills are very well assimilated</td>
<td>4</td>
</tr>
<tr>
<td>$M_{P_1} \in \left[\frac{12}{5}, \frac{16}{5}\right]$</td>
<td>$E^{+}$</td>
<td>Scientific skills are well assimilated</td>
<td>3</td>
</tr>
<tr>
<td>$M_{P_1} \in \left[\frac{8}{5}, \frac{12}{5}\right]$</td>
<td>$E$</td>
<td>Scientific skills are moderately assimilated with decision 1</td>
<td>2</td>
</tr>
<tr>
<td>$M_{P_1} \in \left[\frac{4}{5}, \frac{8}{5}\right]$</td>
<td>$E^{-}$</td>
<td>Scientific skills are insufficiently assimilated with decision 2</td>
<td>1</td>
</tr>
<tr>
<td>$M_{P_1} \in \left[0, \frac{4}{5}\right]$</td>
<td>$E^{--}$</td>
<td>Scientific skills are very insufficiently assimilated with decision 3</td>
<td>0</td>
</tr>
</tbody>
</table>

- Decision 1: Present pedagogical advice that reinforces the various scientific skills.
- Decision 2: Present advice and propose pedagogical situations that reinforce insufficient scientific skills.
- Decision 3: Present pedagogical advice and propose, to be done at home in the form of activities, several pedagogical situations which reinforce the various scientific skills.

### 3 Results and interpretations

We give simulations of student performance in a class that includes thirty students ($N = 30$). The database is filled with 40 results. We present the results obtained from the decision tree which corresponds to the weighting $P_2$, see Figure 2, that of $P_1$ is given in the article [16]. We interpret some results from this tree highlighting the appropriate decisions that need to be made, see Table 4.

### Table 4. Global assessments of scientific skills

<table>
<thead>
<tr>
<th>Result conditions</th>
<th>Number of samples</th>
<th>Level</th>
</tr>
</thead>
<tbody>
<tr>
<td>$M_3 \leq 0.5$ and $M_4 \leq 1.5$</td>
<td>8</td>
<td>$E^{--}$</td>
</tr>
<tr>
<td>$M_3 \leq 0.5$ ; $M_4 &gt; 1.5$ and $M_5 &gt; 0.5$</td>
<td>1</td>
<td>$E^{-}$</td>
</tr>
<tr>
<td>$M_3 &gt; 0.5$ ; $M_4 &gt; 1.5$ and $M_2 \leq 1$</td>
<td>1</td>
<td>$E$</td>
</tr>
<tr>
<td>$M_3 &gt; 0.5$ ; $1.5 &lt; M_4 \leq 2.5$ and $M_2 &gt; 3.5$</td>
<td>2</td>
<td>$E^{+}$</td>
</tr>
<tr>
<td>$M_3 &gt; 0.5$ ; $M_4 &gt; 2.5$ and $M_2 &gt; 3.5$</td>
<td>4</td>
<td>$E^{++}$</td>
</tr>
</tbody>
</table>

The teacher, as the school year progresses, by retrieving the results of science learning skills $C_1$, $C_2$, $C_3$, $C_4$ and $C_5$, can more accurately predict the assessment of his students’ science skills. We give some examples of prediction for $P_2$:

- print("The assessment of scientific skills is ", dtree2.predict([[1, 1, 0, 1, 0]]))

The assessment of scientific skills is [0]. The performance in scientific skills is very insufficient. Provide more teaching situations to do at home to improve each of these skills.
Figure 2. Decision tree for the scientific skills according to $P_2$

- print("The assessment of scientific skills is ", dtree2.predict([[2, 1, 1, 1, 2]])).
  The assessment of scientific skills is [1]. The output in scientific skills is insufficient. Propose other educational situations to improve each of their skills.

- print("The assessment of scientific skills is ", dtree2.predict([[2, 3, 2, 1, 2]])).
  The assessment of scientific skills is [2]. The performance in scientific skills is acceptable. Suggest other teaching situations to improve them.

- print("The assessment of scientific skills is ", dtree2.predict([[2, 2, 3, 2, 3]])).
  The assessment of scientific skills is [3]. The acquisition of scientific skills is successful and the object is achieved.

- print("The assessment of scientific skills is ", dtree2.predict([[4, 4, 4, 4, 3]])).
  The assessment of scientific skills is [4]. The performance in scientific skills is excellent.
We find that the results of the validation tests are consistent when compared with the database. Each time an outcome is known, our database gets richer and more important for decision making and for predicting outcomes.

3.1 The Influence of the "Achieve" skill on scientific acquisition

In this part, we prove the importance of the scientific skill "Achieve" in the overall acquisition of scientific skills. For this we set, for the two weightings $P_1$ and $P_2$, the value $k$ in $\{1, 2, 3, 4\}$ for all the scientific skills other than the "Achieve" skill. Thus, let us set for all $k$ in $\{1, 2, 3, 4\}$ and for all $x$ in $[0, 4]$,

$$P_k(x) = dtree_1.predict([[k, x, k, k]])$$  \hspace{1cm} (5)

and

$$Q_k(x) = dtree_2.predict([[k, x, k, k]])$$  \hspace{1cm} (6)

We present in Figure 3, the two functions $P_2$ and $Q_2$ on the interval $[0, 4]$. We notice that as the values of the "Achieve" skill increase, the acquisition of scientific skills becomes very important. In effect,

$$\forall x \in [0, 4], \quad P_2(x) \leq Q_2(x)$$

In particular

$$\forall x \in [0, \frac{1}{2}], \quad P_2(x) = Q_2(x) = 1$$

$$\forall x \in \left[\frac{1}{2}, \frac{3}{2}\right], \quad P_2(x) = 1 < Q_2(x) = 3$$

$$\forall x \in \left[\frac{3}{2}, 4\right], \quad P_2(x) = 2 < Q_2(x) = 3$$

![Figure 3. The graphical representations of the two functions $P_2$ and $Q_2$.](image)

In the same way if we take $k = 3$, see Figure 4, we find that the function $Q_3$ is greater than $P_3$.

Therefore, the prediction taking into account the $C_3$ component is better and gives an important result in the acquisition of scientific skills. In fact, the decisive scientific competence in the process of the production of scientific learning is the birth of the idea that is going to
be concretized. Indeed, we can appropriate the data, analyze them and proceed to a scientific reflection, validate the idea of reasoning if it is found and communicate it, but having the idea of resolution and moving logically through the process is the most important step in moving towards the target. Thus, prediction 2 is more interesting and more accurate in decision making.

**Figure 4.** The graphical representations of the two functions $P_3$ and $Q_3$

### 3.2 The 'Achieve' skill and the progression of other skills

In this paragraph, we study the influence of the variable values of the skill 'Achieve' with the progression of other skills on the acquisition of global scientific skills. Indeed, we study, in a sense of growth of scientific skills other than the Achieve competence, the behavior of global scientific competence acquisition. We present in Figure 5, the graphical representations of the functions $Q_1$, $Q_3$ and $Q_4$.

Taking into account the results obtained in Figure 5, we have:

\[
\forall x \in [0, \frac{1}{2}], \quad Q_1(x) = 0 < Q_3(x) = Q_4(x) = 1
\]

\[
\forall x \in [\frac{1}{2}, 4], \quad Q_1(x) = 1 < Q_3(x) = 3 < Q_4(x) = 4
\]

We deduce that, when the scientific skills other than the skill "Achieve" increase the acquisition of Knowledge becomes interesting. We also notice that there exist a correlation between the skill "Achieve" and the other scientific skills, and that this skill is interesting in the learning operation.

### 3.3 Harmonization between "Analyze & reason" and "Achieve"

We study in this paragraph the relation which exists between the competence "Analyze and reason" and the competence "Achieve" and we indicate the type of correlation which exists between these two competences.
For this we consider the function $f$ defined as follows: For all $x$ in $[0, 4]$, for all $y$ in $[0, 4],$

$$f(x, y) = dtree2.predict([[2, x, y, 2, 2]])$$  

(7)

$x$ represents the value of the "Analyze and reason" skill and $y$ represents the value of the "Achieve" skill. We present in Figure 6, the representation of the function $f$, it is more general than figure 3, indeed for $x = 2$, we find $\forall y \in [0, 4] f(2, y) = Q_5(y)$.

We study the behavior of the two skills "Analyze and reason" and "Achieve" to acquire very precise scientific knowledge and we discuss how they react in complementarity, see Figure 6. For this we go on to visualize the level curves to highlight the complementarity of these two skills to reach a well-defined level of overall skill, see Figure 7.
Figure 7. The level curves of the function $f$

We note that if the value of the skill "Analyze and reason" is small (strictly less than 1), it is necessary to provide a significant effort in the acquisition of the skill "Achieve" to have a skill acquisition result equal at 1.25 or 1.50 or 1.75. On the other hand, if the value of the "Analyze and reason" skill is greater than 1, an average effort is needed in the acquisition of the "Achieve" skill to have a sufficient skill acquisition result, i.e. greater than or equal to 2.00 (2.00, 2.25, 2.50, 2.75). Thus, as long as the "Analyze and reason" skill acquisition phase is fairly well done, the "Achieve" skill acquisition phase becomes decisive, indeed even an average value of this skill influences the overall acquisition of scientific skills.

### 3.4 Pedagogical means to improve the skill "Achieve"

Taking into account the results obtained in this research, the teacher must give particular importance to developing the skill "Achieve". We present, in this sub-section, some pedagogical means that can help the teacher to develop this skill, we cite:

- Get used to following a logical thinking process by asking the following questions: what do we have, what do we seek and how do we obtain what we seek. In fact, we will get used to proposing suggestions for reasoning.
- Partition the objective to be achieved and know the characteristics of each component of this objective and try to link it with the initial data and information.
- Try to apply similar approaches already treated before and which have the same properties as the objective to be achieved.
- Proceed to a global vision on the data, the analysis and the reasoning made in order to allow an interactive reflection between the information and the objective and not is restricted to treat a part of the data components.
- Give game situations that involve the reconstruction of different shapes whose objective is to build a specific shape. This can help the learner take logical and justified steps to have the final form.
4 Conclusion

We are interested in scientific skills as an effective learning process whose objective is to provide learners with a mechanism for scientific thinking. Therefore the learner will have a methodological attitude that allows him to interact effectively with the different situations in his social and economic environment. In this work, we have proven the importance of the skill "Achieve", for the scientific subjects, we have offered some pedagogical means to help the teacher to develop this skill in his students. Admittedly, all scientific skills are important in the construction of Knowledge, but the "Achieve" skill is essential for the birth of ideas that converge towards the targeted objective. All skills are strongly correlated but the one that is the pillar of any progress towards the desired result is the skill "Achieve". The procedure described in this work, which uses artificial intelligence based on the decision tree, offers the teacher opportunities to predict the level of his students in scientific skills and consequently to remedy situations of difficulty and more interested in accomplishing the "Achieve" skill. Obtaining new results makes it possible to build a new database and the decision-making by our system will become more precise. We could also take an interest in the personalized evaluation of the "Achieve" skill of each learner by monitoring their performance in this skill in order to offer the educational situations appropriate to their learning level. As a result, we present an equity for the learners to acquire the scientific skills.

References


