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Assessment of Learners' learning about Temperature and Heat concepts

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ABSTRACT

Heat and temperature are two central concepts in all studies of thermodynamics and thermochemistry. The analysis and understanding of the majority of physical and chemical phenomena depend mainly on a good understanding of these two concepts, especially when it comes to a study in both the microscopic and macroscopic registers. Practitioners in the teaching of physical sciences find that there are real difficulties for learners to understand the concepts of heat and temperature and to differentiate them.

In this context, we aim to highlight the effect of the sequence, progression and continuity of the content of teaching guidelines, textbooks and school programs concerning these two concepts for each level of study, identify the difficulties teachers face when managing lessons in temperature and heat. This research seeks to answer the following problem: To what extent does the use of teaching instructions, curricula and textbooks contribute to constructing concepts in an orderly and progressive manner which contributes to improving teaching and understanding heat and temperature concepts and to distinguish them?

In order to provide a solution to this problem, we have, on the one hand, conducted a documentary study to see to what extent the content of teaching guidelines and textbooks is respected and incorporated for the construction of cognitive concepts in the fields of heat and temperature according to school levels. On the other hand, we carried out a field study based on a diagnostic evaluation (supported by a scale) for three promotions of student teachers, 2016/2017, 2017/2018 and 2018/2019, in order to closely examine their level of knowledge regarding the two previous concepts, and to identify difficulties and obstacles. Some appropriate solutions have also been suggested.

Key words: thermochemistry, heat concept, temperature concept, diagnostic test, school path.

1. INTRODUCTION

We propose to carry out a study on the temperature and heat greatness because on the one hand, these two quantities play a fundamental role in physics - chemistry and more broadly in all sciences, on the other hand, heat and temperature are at the heart of societal debates related to sustainable development. F. Halbwachs **Error! Reference source not found.** notes that heat has a very different status from temperature since. "It is connected with hot and cold sensations only precisely through the temperature. Temperature is considered a state of the bodies that can be spotted on a scale". The question of learners' conceptions of temperature, heat and the distinction between these two concepts has been the subject of many studies 1-9. Other studies have been conducted by M.L. Zimmermann **Error! Reference source not found.**, in his thesis entitled "concept of heat, contribution to the study of students' conceptions and their uses in a learning process". On the other hand, many studies have been done on the subject of teaching heat 12-14. Recently, several authors 1517 have pointed to the need for "progression" throughout schooling, from the beginning of primary to the end of secondary. The objective of this study is to measure the degree of understanding and to distinguish between the temperature and heat concepts by the learners compared to the other elements of the chemistry module, and to highlight the logics that structure the official texts for these two concepts and the interpretation that is made of them in the textbooks. This article first proposes a detailed statistical study of a diagnostic test, conducted among new professors recruited during the years 2016/2017, 2017/2018 and 2018/2019 validated three times during these years. In a second step, we will propose an analysis of the programs, the booklets of scientific activities and textbooks from primary to secondary in technology and physical sciences in consultation with the official instructions and the ministerial circulars. What progression of heat education do they offer?

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2. RESEARCH METHODOLOGY

The global sample during the three years of research is made up of 168 beneficiaries with a license or a master's degree, with 56 beneficiaries per year, who have successfully completed the competition of the regional education and training academies (AREF), written and oral, for the three school years 2016/2017, 2017/2018 and 2018/2019. Like all years at the CRMEF, one week is devoted to diagnostic tests for new recruits whose purpose is to measure, on the one hand, the skills acquired or not acquired in the chemistry module throughout their school curriculum that they will use during their year of study and their ability to initiate new learning during the training period and to plan a training device that takes into account the remedies and regulations to be applied, and this to have effective training and to differentiate between beneficiaries. Another objective of this test is to measure the general level of disciplinary knowledge in chemistry of the beneficiaries compared to those of the two previous years. This test has been validated several times with the groups of the years 2016/2017 and 2017/2018. It includes 27 items that cover all the essential concepts of the element of the chemistry module.

1.1 Procedure of the counting of the diagnostic test

The 56 beneficiaries of each year were divided into two groups G1 and G2. Each group has three different scales and the correctness of the test. The counting of the copies of the group G1 is established by the group G2 and vice versa. The statistical laws used in this study were prepared and provided by the trainer as follows:

Percentage and Overall Percentage of Successful Questions

$$PQR = \frac{\text{Number of teachers who passed the questionnaire}}{\text{Total number of professors who passed the test}} \times 100$$

$$PQRG = \frac{\sum_i PQR}{\text{Total number of theme questions}}$$

Percentage and Global Percentage of False Questions

$$PQF = \frac{\text{Nomber of the teachers who did not pass the test}}{\text{Total number of professors who passed the test}} \times 100$$

$$PQFG = \frac{\sum_i PQf}{\text{Total number of theme questions}}$$

Percentage and overall percentage of unanswered questions

$$PQNR = 100\% - (PQR + PQF)$$

$$PQNRG = 100\% - (PQRG + PQFG).$$

1.2 Docimological study

There are multiple scales for correcting multiple choice questions. According to Leclercq (1987) **Error! Reference source not found.**, a scale is a set of tariffs (Table 1). The tariff being a consequence agreed upon in advance for a precise answer. To make our work more constructive we have corrected this test three times using three different scales for the three promotions, this is in order to know which is the scale which is the most adapted for the choice of the good candidate and on the other hand to compare the score of the group 2018/2019 with the score of groups 2016/2017 and 2017/2018.

Table 1 : Quality of questions and significance of scores 18

Scale 1 (simple)	+1 if the answer is correct -1/3 if the answer is incorrect 0 if abstention
Scale 2 (symmetrical)	+1 if the answer is correct 0 if the answer is incorrect 0 if abstention
Scale 3 (with penalty for riddle)	+1 if the answer is correct -1 if the answer is incorrect 0 if abstention

3. RESULTS AND DISCUSSIONS

The sample is composed of 35 graduates and 15 masters, ie 50 candidates in total (6 candidates have dropped out). According to scale 2 (symmetrical scale), there are only 8 candidates in the sample who have an average between 9 and 16; 16% of the sample studied, of which 6% have a master's degree and 10% a license. The best grade was obtained by a licensee.

- According to the simple scale 1,6% of the sample studied have a score close to the average and concern only the licensees, 8% have a score below zero and the major is a licensee with a mark of 10,95/20.
- Counting according to scale 3 (with guessing penalty) showed that all candidates are very far from the average, with 32% having a note below zero, 42% having a note above zero and 2% with a note of 00/20.
- By comparing the scores obtained by each candidate according to the three scales, we note that only 6% of the candidates who are made redundant have a note above the average according to the simple and symmetrical scale.

For the same diagnostic test, the comparative study of the result (promotion 2018/2019) thus found with this obtained for the promotions of the years 2016/2017 and 2017/2018, according to the three scales, shows that the number of candidates having the average for the promotion studied remains very low (Table 2, Figure 1, 2& 3).

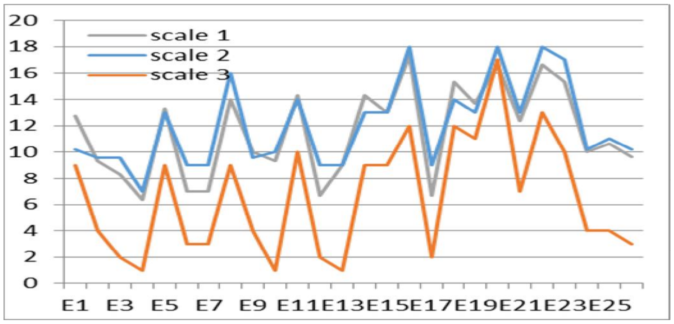


Figure 1: Evolution of the notes obtained by each candidate according to the three scales during 2017

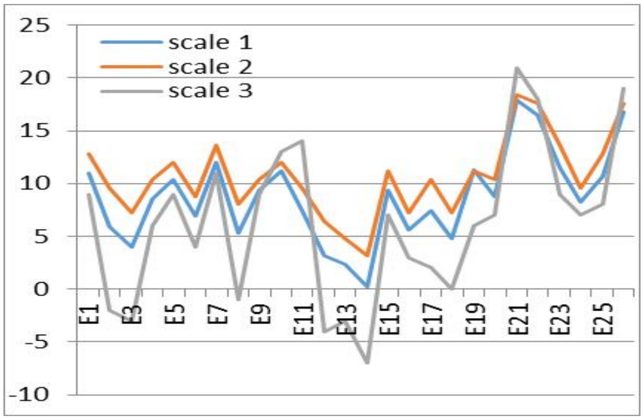


Figure 2: Evolution of the notes obtained by each candidate according to the three scales during 2018**.**

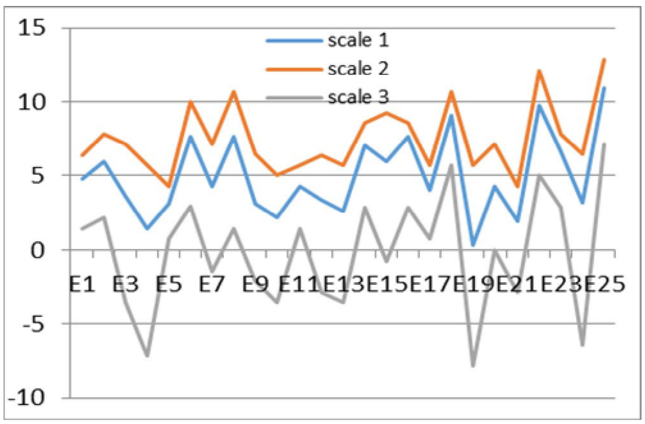


Figure 3: Evolution of the notes obtained by each candidate according to the three scales during 2019

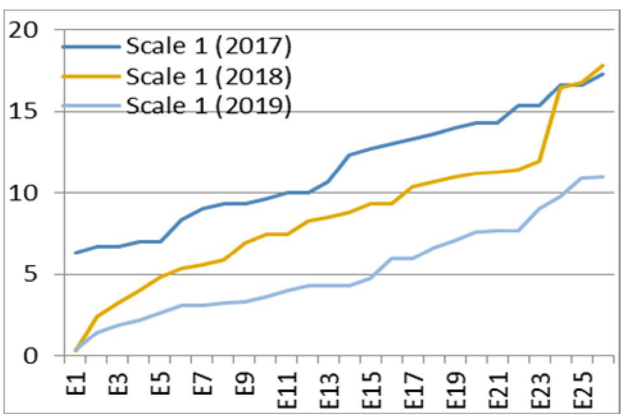


Figure 4: Evolution of scores obtained by each candidate according to the simple scale during 2017-2018-2019

Curve 4 represents, according to the same scale (simple for example), the comparison of the marks obtained by the candidates during the three years of study. The candidates were ranked in order of merit: candidate E1 corresponds to the one with the lowest score, E26 corresponds to the candidate with the highest score. This curve shows more clearly that the level of candidates is decreasing from year to year.

4. RESULTS OF THE DISCIPLINARY STUDY

The results of the diagnostic evaluation carried out over the three years showed that the level of knowledge in the chemistry module of recruits decreased significantly from one year to the next (Figure 1). This drop in level is confirmed by the score obtained in the diagnostic test of these promotions (Table 2, Figure1). What attracted much more attention is the very marked decline in recruitment in kinetics and thermochemistry compared to the other elements of the module. In this study, our work will focus solely on thermochemistry.

Item 27, Diagnostic Test, on the Thermodynamic Theme, includes four correct propositions, specifically for the distinction between temperature and heat. The counting of this item, during the school years 2016/2017, 2017/2018 and 2018/2019, showed that fifteen candidates of the 2016/2017 class, the equivalent of 27%, ten candidates of the 2017/2018 class the equivalent of 18%, and only two candidates (master) of the 2018/2019 class, the equivalent of 4%, gave the four fair proposals.

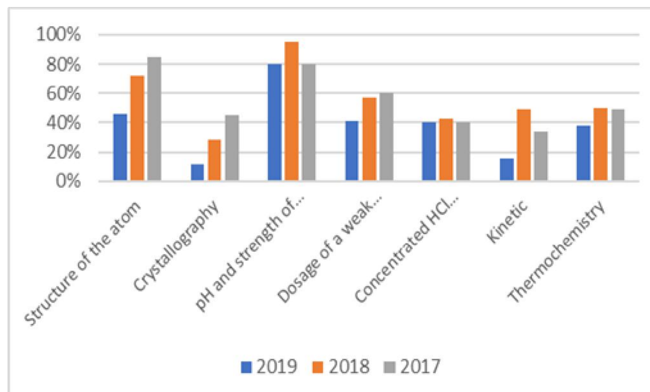


Figure 5: Evolution of disciplinary levels of learners, in the chemistry module, between 2017,2018 and 2019

In the following section, we will seek to identify the factors that contributed to the lack of understanding and non-distinction between the two concepts of temperature and heat among learners from primary to university. The didactic transposition, the content of textbooks, programs and official instructions of the different levels, will constitute the field of our research.

Case Study: What progress in teaching temperature - heat concepts from school and / or high school to university?

The results (table 2, 3 and 4), of the same diagnostic test, carried out among the new teachers recruited during the years 2016/2017, 2017/2018 and 2018/2019, highlighted the existence of enormous difficulties for these teachers recruited at the level of the two concepts temperature/heat which are central concepts of the chemical thermodynamics, and the distinction and the relation between them.

Table 2: Official instructions and program of physics 1st year Baccalaureate.

<table>
<tr><th colspan="3">Official Instructions of Physics 1st year Baccalaureate: Mathematical and Physical Science</th></tr>
<tr><th>Contents</th><th>Proposed activities</th><th>Knowledge and skills</th></tr>
<tr><td>- Thermal energy: thermal transfer
- Massic heat of a pure body.
- Heat quantity Q = m.c. ΔΘ and its conventional sign.
- Thermal equilibrium
- Calorimetric equation.
- Latent heat of change of state of a pure body.
- Other form of energy transfer: Radiation.</td><td>▪ Simple experiments to put in evidence related variables to the amount of heat.
▪ Quantitative experimental study of thermal transfer between two bodies to determine:
- Calorific capacity of a calorimeter
- Massic heat of a metal.
- Latent heat of change of physical state of a solid body.
- Experiences or examples of the daily life of the learner or documents and software to put in evidence other mode of energy transfer: Radiation.</td><td>▪ Know that heat forms one of the forms of energy transfer.
▪ Know how to use the expression of the amount of heat Q = m.c.ΔΘ and know his unit.
▪ Know the thermal balance and its application.
▪ Know the latent heat of change of state and its unity.
▪ Determine calorimetric capacity, mass heat and latent heat.
▪ Know the radiation is a form of energy transfer.</td></tr>
<tr><td>- Work and internal energy
- Effect of work: temperature increase - elastic deformation - change in physical or chemical state
- Work of forces applied to a quantity of perfect gas.
- Notion of internal energy
- 1st principle of thermodynamics.</td><td>▪ put in evidence some effects of work received (temperature increase, change in physical or chemical state) using experiences or examples of the learner's daily life or documents and software (elastic deformation).
▪ put in evidence different forms of energy exchange of a mechanically isolated system.</td><td>▪ know the expression of the work of pressing forces and its exploitation.
▪ know the notion of internal energy.
▪ know the expression of the internal energy of a system.
▪ Know the 1st principle of thermodynamics and its exploitation.</td></tr>
<tr><td>Part of program : Work and Internal Energy (Mathematical science)</td><td colspan="2">- Work effects: elastic deformations, temperature rise, changes in physical or chemical state.
- Work of the forces applied to anperfect quantity of gas
- Notion of internal energy.
- First principle of thermodynamics.</td></tr>
<tr><td>Part of program :
Thermal energy: Thermal transfer (Mathematical science)</td><td colspan="2">- Massic heat of a pure body.
- Heat quantity Q = m.c. ΔΘ and its conventional sign.
- Thermal equilibrium - Calorimetric equation.
- Latent heat of change of physical state of a pure body.
- Other mode of energy transfer: Radiation.</td></tr>
</table>

Table 3: Content related to temperature and heat in school manuals of physics 1st year Baccalaureate.

contents	Proposed activities	knowledge and skills
Physical transformation of matter. - Heat and temperature - Physical transformation of matter.	▪ Realization of simple experiments to measure the temperature. ▪ Realization of the experiments of the transformation of the matter.	▪ Differentiation between temperature and heat. ▪ Determination of temperature using a thermometer. ▪ Know that the degree Celsius and the unit of temperature. ▪ Know the different types of physical transformation of matter (fusion, solidification, condensation and vaporization).
Instructions	▪ Reminder on the prerequisites of learners in primary school around the notions of heat and temperature. ▪ Exploit the prerequisites to correct the false representations of the learners.	
Part of program : The matter and environment	**Physical transformation of matter** ▪ Heat and temperature. ▪ Physical transformation of matter. ▪ Explanation of the physical transformation of matter using the atomic model.	

Table 4: Official instructions and program of physics 1st year college.

School Manual	objectives	Proposed experimental activities
Thermal energy: Thermal transfer	- Know than heat is a form of energy transfer. - Know how to use the expression of the amount of heat $Q = mc\Delta\Theta$ and know his unit. - Define the thermal equilibrium and apply the corresponding relation. - Define the massic heat of a metal and its unit. Determine heat capacity, massic heat and latent heat. - Know that radiation is a mode of energy transfer. - Know how to apply the first principle of thermodynamics (reserved for 1st math science).	- Massic heat of a pure body. - Heat quantity $Q = m.c.\ \Delta\Theta$ and its conventional sign. - Thermal equilibrium - Calorimetric equation.. - Latent heat of change of physical state of a pure body. - Other mode of energy transfer: Radiation

On this observation, the following question arises: what is the position of Moroccan curricula and textbooks in this respect from the beginning of primary to the end of secondary education? What progress in teaching temperature and heat do they offer?

4.1. Analysis of programs, school manuals in consultation with official instructions.

Why analyze textbooks? First, textbooks are resources for teachers that they can use to interpret official instructions. They thus constitute a reference for teachers. Second, the textbooks offer examples of sequences that teachers are likely to implement in the classroom. Although their study does not prejudge what is achieved in classrooms, textbooks are interesting indicators because of their position between prescription and reality of the class.

We present here an analysis of the contents of the programs, the textbooks from the official instructions according to the different levels and this with the aim:

- To have an overview on the teaching of temperature and heat and the different didactic strategies that have been proposed to establish a progression of the teaching of these two concepts.
- Examine the way in which the various "ingredients" required to achieve the principle of heat exchange are introduced, whether they are present or not and at what level they appear. We list the contents corresponding to the different levels in the table 3.

According to the increasing order of educational attainment, textbooks, curricula and official instructions present, from the 5th year to the 6th year, an energy education in which the various sources of energy, the transformation of energy, different types of energies, fossil and renewable energies, electric power generation, energy consumption, energy saving, and societal issues related to energy. The programs, official instructions and manuals deal with the concept of temperature at the level of the 1st year of the college by citing the use of the thermometer to measure the increase of the temperature of a body, the changes of state ... From the 2nd year of secondary school to the first year of secondary qualifying (common core), no indication of the two concepts of temperature and heat, which shows a wide range of rupture.

At the qualifying secondary level, in the first year of the Baccalaureate and only for the mathematical sciences and physical sciences options, these textbooks show a quantitative study: heat exchange between hot and cold body, measurement of mass heat capacity and heat of a body, and subsequently new rupture, because there is absence of any notion integrating the concepts of temperature and heat at the level of 2^{nd} year of high school diploma qualifying.

4.2. The "ingredients" for learning about heat and temperature concepts in programs and manuals.

As shown in the table 3, Energy sources or "energy resources" are included in the programs and textbooks in primary (5^{th}, 6^{th}) and 1st year secondary school. Whether in programs or textbooks, they are always addressed from the perspective of energy education for these last levels. One of the recurring objectives is to distinguish between renewable and non-renewable sources of energy. Several confusions are to be reported at the secondary level. First, the first confusion pointed out by Vince and Tiberghien **Error! Reference source not found.** in Bac programs and textbooks of the 1st year concerns the confusion between form and mode of energy transfer. For example, the use by programs and textbooks of the term "thermal energy", without it being defined, can contribute to such confusion. Indeed, in the chapter dedicated to the mechanical energy of a mobile that descends on an inclined plane, the textbook of the 1st level Bac emphasizes, in the case of friction, that there is loss of mechanical energy in the form of heat: Q=W (rub). For the same level, in the chapter dedicated to "thermal energy": Thermal transfer for the section Mathematical and physical sciences, the manual mentions that the heat is due to the temperature variation $Q = m\ c\ \Delta\theta$ and in the chapter energy transfer in an electrical circuit, the manual indicates that a portion of the energy received by a receiver is transformed as heat $W = Q = Ri^2\Delta t$. Through this analysis, we found that transformations are present in primary school curricula and textbooks in a perspective of energy education and in more detail (quantitative and qualitative study) in those of the 1^{st} year. As for the programs and textbooks of the 2^{nd} year Baccalaureate, there is no explicit mention.

These expressions (explicit forms) in which different variables with different appointments appear in textbooks, the absence of a general definition of thermal energy and ambiguity in vocabulary can hinder a clear differentiation between different aspects of heat, especially between sources, forms and modes of energy transfer. However, an "ingredient" for mastering the distinction and the relationship between temperature and heat, which some authors claim is important, is not introduced by official programs and instructions and is not addressed in the manuals: the register microscopic material (substantialist design) that has not been exploited in any textbook.

In our view, for learners to understand the meaning of the heat concept and to relate it to temperature in different situations, it is essential to bring out the unification function throughout schooling in relation to these two concepts. the continuity function of the ingredients related to these two concepts, which can hardly be envisaged without recourse to general and precise definitions of heat and temperature and to microscopic studies of matter (substantialist model). For example, the change of state temperature is a characteristic quantity of a constant pressure substance. Definitions of these two concepts will have to be equivalent to ensure consistency and distinction between, even if the heat formulation is to be adapted to each level.

On the other hand, it is not necessary to introduce the heat-temperature differentiation from the study of the change of state, but to make this difference understood by other means: the change of temperature of change of state astonishes the 1st year college students. Indeed, the coexistence of the two phases, at the moment of the change of state, is not known by the learners. Thus we must take into account the fact that learners (1^{st} college) often remain fragmented and scattered.

In conclusion, according to the results of our analysis, the acquisition of this differentiation is difficult, because the content of the teaching as stipulated in the textbooks, the programs and the official instructions is in contradiction with the conceptions initials of learners. On the other hand, the notions concerning the two concepts and their field of application do not follow a continuous function throughout the learner's schooling: the presence of breaks (absence of these notions) of the order of 4/6=67% for secondary content this is the equivalent of: over six years of schooling in high school these notions appear only in the first year college and first year Bac is two years of awareness of these concepts. This justifies the difficulties in the understanding and differentiation between the heat/temperature concepts of the thermochemistry module, in academics.

5.CONCLUSION

This study suggests that textbook designers and actors in the school process need to have a clear strategic vision to integrate each concept (temperature / heat) at each level of education, throughout the learner's schooling. while taking into account the didactic transposition that varies from one level to another, and the learning style of the learner. The ingredients of these two concepts must be introduced in a progressive way according to the level and the school cycle.

The results of this study showed that the academic level and the level of competence of the students in the chemistry module had greatly decreased in recent decades, especially in the fields of chemical thermodynamics and kinetics.

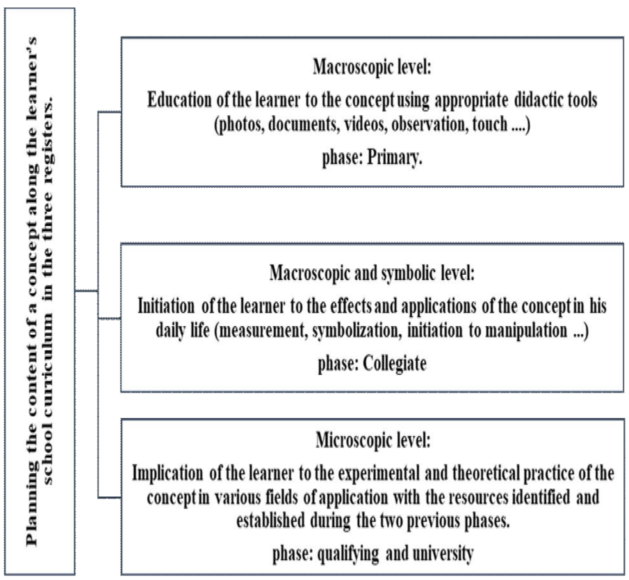
This controversial decline is due to several reasons, including:

- The lack of a clear and precise vision in the development of curricula, textbooks and official instructions.
- The elaboration does not take into account the factor of continuity and graduation of academic levels in terms of knowledge and skills.
- Study contents do not take into account the accelerated technological development, the economic, social and cultural

factors of the learner and are not tested before being officially approved.

- The decline in the level of supervision in universities both quantitatively and qualitatively.
- At the end of his schooling or university career, the learner finds himself unable to keep pace with the labor market because what he has learned at school is not compatible with the demands of the labor market job.

Based on the results of this study, we propose a modeling allowing the conceptual planning of the content of an academic or professional training device. This proposal requires that the content of each phase (level) of planning should meet a number of recommendations: Harmonization, articulation and continuity



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