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The barriers to developing critical thinking in life and earth sciences curricula in Tunisia

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ABSTRACT

The purpose of this research is to analyze the life and earth science curricula in Tunisia in order to determine its characteristics and to know if it really helps to develop critical thinking as it is claimed in curriculum documents. In this analysis, the authors applied the revised Bloom's taxonomy. The results show that curriculum authors ignore the more complex cognitive processes and the most abstract knowledge, which leads to imagine that there is a barrier to encountering the higher levels which makes it impossible to develop critical thinking among students.

Keywords: Curriculum analysis, Bloom's revised taxonomy, critical thinking.

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INTRODUCTION

The "Life and Earth Sciences" is a very important discipline in scientific and general education. By the nature and the richness of its objects of study, the diversity of its methods and investigative techniques, Life and Earth Sciences represent a variety of media to give students insight into a broad scientific culture and to help develop their various capacities on the cognitive, social, behavioral and sensorimotor level. One of the main goals of education, regardless of level, is to help develop thinking skills including critical thinking skills (Gelder, 2005). Ennis (2016) argued that the best way to teach critical thinking is that of combining with a subject matter not teaching it in a stand-alone course. The authors of the life and earth sciences programs in Tunisia are not the exception by recommending to develop a scientific attitude characterized by curiosity, precision, objective judgment and critical thinking.

The most popular definition of critical thought is that given by Ennis (1991): critical thinking is "reasonable and reflective thinking focused on deciding what to believe or do." Critical thinking is the top level thinking in Bloom's taxonomy which has the following characteristics: analysis, evaluation, reasonability and reflection. It operates in terms of criteria; it is self-correcting and context sensitive; as well as it allows us to make judgments about the world (Jeevanantham, 2005). Most educators agree that it is essential for students to develop these skills while engaging in academic learning because it allows them to be engaged in objective judgment and leads to self-regulation (Behar-Horenstein and Niu, 2011). Critical thinking requires an individual's active participation in the act of reflection and going beyond the mechanical recitation of the information that has been seen in many classrooms (Dlamini, 1999). Sternberg (Behar-Horenstein and Niu, 2011) recommends that curriculum authors concentrate on strengthening the intellectual functioning of students' meta-components, performance components, and knowledge acquisition strategies. Meta-components refer to the higher mental processes that require planning, monitoring and evaluation of individuals' actions.

This article aims at investigating the characteristics of Tunisian curricula of life and earth sciences and whether those curricula develop the skills of critical thinking or not. Bloom's Taxonomy of Educational Objectives is an important framework both for developing course assignments and for serving as a yardstick against which to measure evidence that critical thinking has occurred (Nentl and Zietlow, 2008).

The authors propose to analyze the curriculum of life and earth sciences of secondary education in Tunisia. This teaching starts with the first secondary form

common grade three sections and ends with the fourth form that has a national examination: the baccalaureate. The teaching of life sciences and earth lasts from 1 to 4 hours per week and varies by level and section. Knowledge areas covered by the discipline is related directly to the human's life, health, relationship with the environment, use of biological and geological resources, which gives the material a high educational value – because it is constituted by values , attitudes and behaviors conducive to health and the environment. To accomplish our investigation we applied a widely used instrument in the analysis of curricula: the Revised Bloom's Taxonomy. By using this analysis we will try to answer the following research questions: What are the general characteristics of the Life and Earth sciences in the Tunisian curriculum? What are the cognitive skills required from learners' levels? Does this curriculum potentially help develop critical thinking among students?

High-level cognitive processing involves making inferences, drawing conclusions, synthesizing ideas, generating hypothesis, comparing and contrasting, finding and articulating problems, analyzing and evaluating alternatives, monitoring thinking (King, 2002).

A number of researchers have recommended using particular instructional strategies to encourage the development of critical thinking skills and abilities, such as explicit instruction, collaborative or cooperative learning, modeling, and constructivist techniques (Lai, 2011).

Overview of the revised bloom's taxonomy

Analysis of a program can highlight the cognitive demands on children throughout the duration of their formal schooling (Lee et al., 2015). The most used and well-known taxonomy in the educational settings is Bloom's taxonomy from 1956, but more taxonomies have been developed and revised since then (Näsström, 2009).

Bloom in 1956 and an educator group developed an objective classification system: the taxonomy of educational objectives. This original taxonomy consists of three respective fields: the cognitive domain, the affective domain and psychomotor domain (Bloom et al., 1956). The cognitive domain consists of six categories ranging from simple to complex: knowledge, comprehension, application, analysis, synthesis and evaluation. This taxonomy had permeated teaching and instructional planning for almost 50 years but it was criticized by Lorin Anderson, Krathwohl and a group of educational psychologists and educators (Anderson and Krathwohl, 2001). This taxonomy has an anomaly which is the unidimensionality. In fact, the *Knowledge* category embodied both noun and verb aspects. The noun or subject matter aspect was specified in *Knowledge's* extensive subcategories. The verb aspect was included in the definition given to *Knowledge* in that the student was expected to be able to recall or recognize knowledge (Krathwohl, 2002). This anomaly was eliminated in the revised Taxonomy by allowing these two aspects, the noun and verb, to form separate dimensions, the noun providing the basis for the Knowledge dimension and the verb forming the basis for the Cognitive Process dimension (Krathwohl, 2002).

The Knowledge dimension contains four instead of three main categories ranging from concrete to abstract (Figure 1). The fourth and new category is the metacognitive Knowledge. First, the factual knowledge represents the elements of information related to a discipline; it includes the facts and terminology. Second, Conceptual knowledge is knowledge of concepts, their characteristics and relationships. Third, procedural knowledge is a series of steps to accomplish a task. And finally, metacognitive knowledge is that an individual has of his or her cognitive processes, strengths and weaknesses.

In addition, the cognitive process dimension contains six categories ranged from low to high cognitive complexity (Figure 2). Three categories were renamed, the order of two was interchanged, and those retained categories' names were changed to verb form (Krathwohl, 2002).

Finally, the knowledge and cognitive processes can be combined as a double entry table: The taxonomy table classifies the objectives, activities and evaluation in a clear, precise and concise way (Krathwohl, 2002).

METHODOLOGY

The learning objectives covered by this analysis are the explicit goals drafted by the Directorate of Educational Instructors & Standards from Cycle Preparatory and Secondary Education as part of the curriculum from September 2009. The classification of the specific objectives was carried out by our team of five researchers in science and life education. These researchers were trained on the original and the revised taxonomy.

In a first step each participant classifies the objectives that are offered to him/her alone. Then, in a collective presentation and following discussions we are agreed on the right category. In general, there is no conflict to report in the categorization that can distort the results of the research.

These objectives were, in first, classified according to the Bloom field of taxonomy in the cognitive domain, affective or psychomotor. Secondly, we were interested in the cognitive field goals that are most important in our research. Each goal is represented in two dimensions: the dimension of knowledge form as the vertical axis of the taxonomic table and the dimension of the cognitive process as the horizontal axis. The intersections of the categories of knowledge and cognitive processes would form the cells.

To see how this investment objective is accomplished, consider the following examples taken from the life science and the earth curriculum in 2009:

Example 1

Objective 1 (O1): Identify ovarian structures and stages of folliculogenesis and oogenesis.

This objective is in fact formed by three sub goals:

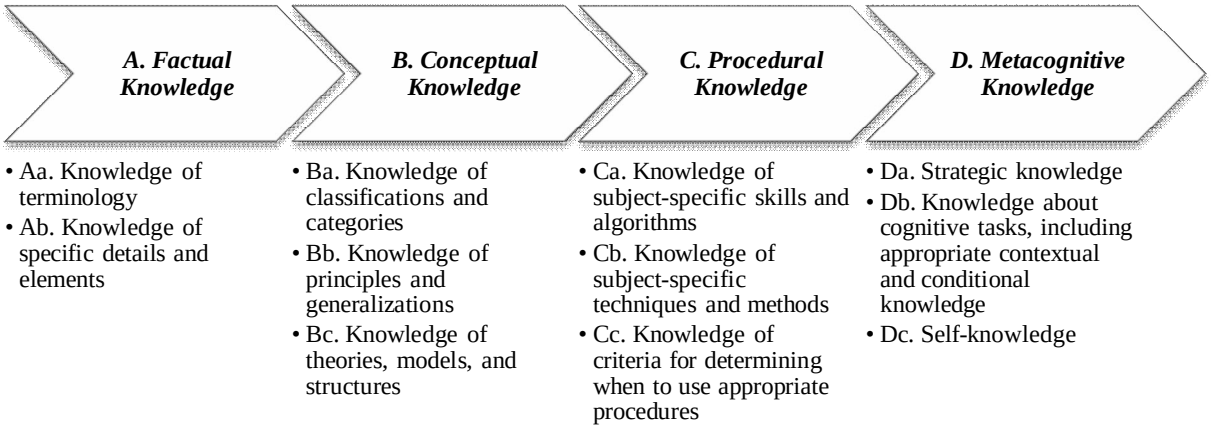

Figure 1. The Knowledge dimension from concrete to abstract. Source: Adapted from Krathwohl (2002).

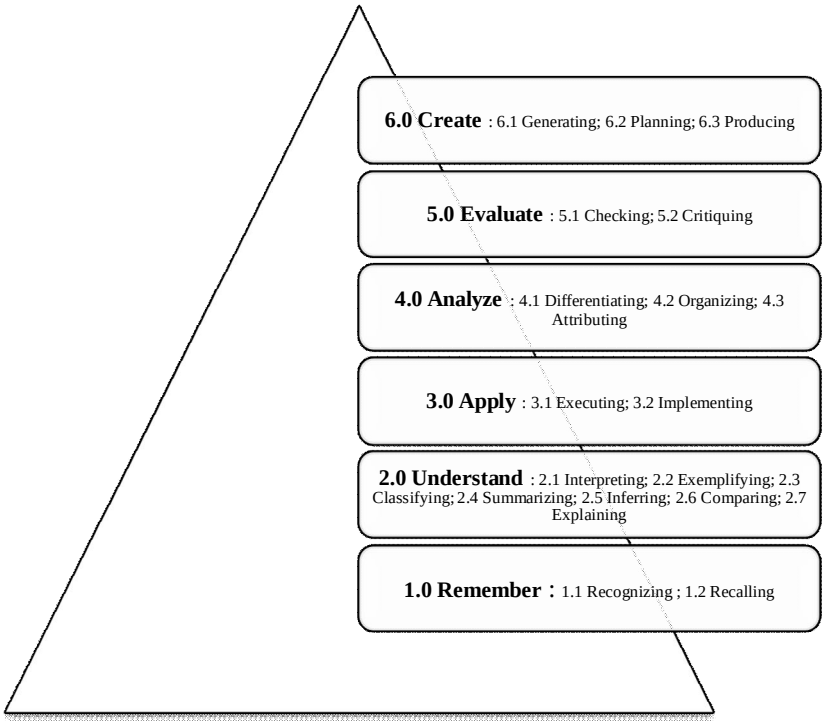

Figure 2. Structure of the Cognitive Process Dimension of the Revised Taxonomy from less complex to high complex. Source: Adapted from Krathwohl (2002).

i) Objective 1a. (O1A): Identify ovarian structures
ii) Objective 1b. (O1b): Identify the steps of the folliculogensis
iii) Objective 1c. (O1C): Identify the steps of oogenesis

To classify the objective according to the dimension of the cognitive process we raised the action verb *identify* which in this case means locating knowledge in long-term memory That Is consistent with material presented. This verb belongs to 1.0. Remember category and sub category 1.1. Recognize. To classify the objective that the dimension of knowledge: ovarian structures ranks in Bc. Knowledge of theories, models, and structures which is a sub category of B. Conceptual Knowledge. However, steps in folliculogensis or oogenesis belong to another category under Ba. Knowledge of classifications and categories

Example 2

Objective (O2): Explain how the relief is represented on a topographic map.

The verb in this case is explained. It is classified in the second

Table 1. The classification in a taxonomy table of the two objectives of Tunisian curriculum.

		Cognitive process level																		
		1.1	**1.2**	**2.1**	**2.2**	**2.3**	**2.4**	**2.5**	**2.6**	**2.7**	**3.1**	**3.2**	**4.1**	**4.2**	**4.3**	**5.1**	**5.2**	**6.1**	**6.2**	**6.3**
Knowledge level	Aa.																			
	Ab.																			
	Ba.	O1b O1c																		
	Bb.																			
	Bc.	O1a																		
	Ca.																			
	Cb.									O2										
	Cc.																			
	Da.																			
	Db.																			
	Dc.																			

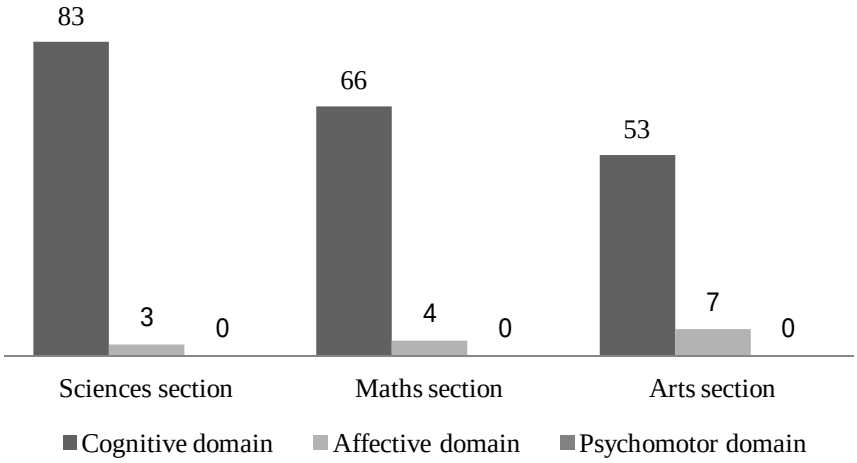

Figure 3. Number of specific objectives identified in the Tunisian official programs of different sections.

category of the dimension of the cognitive process that is 2.0 Understand and subcategories 2.7 explaining and the dimension of knowledge belongs to C. Procedural Knowledge and exactly Cb. Knowledge of subject-specific and technical methods.

So we can draw the taxonomy table as shown in Table 1. After completing the classification of all objectives, the percentage is determined for each table cell in the three sections studied.

RESULTS

In Tunisian curricula, the learning objectives are more numerous in science section (n = 83) compared to those in the math section (n = 66) and those in the arts section (n = 53). This may be due to the difference in the schedules of the life and earth sciences in the course. The learning objectives in the cognitive domain are recommended in the high school program at the expense of the affective goals that have few mentioned (Figure 3). We note that curriculum authors claim to develop sensorimotor skills (manipulative skills, handling of instruments of observation and measurement, drawing ...). However, in the recommendations they completely ignore such goals.

Knowledge areas covered by the discipline (biology, geology) relate directly to human life, its health, its relationship with the environment and the use of biological and geological resources. This means the educational material consists of values, attitudes and behavior favorable to health and the environment.

Curriculum analysis of three sections shows that curriculum authors have used 18 action verbs to develop the objectives of the cognitive domain (Table 2). These action verbs are unevenly distributed between first sections and levels of learning. We note that the action verbs are the same in the first level in the different sections analyzed. Typically, curriculum authors have

Table 2. Action verbs used to formulate specific goals in the three analyzed curricula (%).

Action verbs	Science section				Math section				Arts section			
	Level 1	Level 2	Level 3	Level 4	Level 1	Level 2	Level 3	Level 4	Level 1	Level 2	Level 3	Level 4
Explain	25	31	50	69.2	25	31	44	56.3	25	11.1	25	58.3
Identify	31.2	20.7	6.3	3.9	31.2	20.7		18.7	31.2	11.1	37.5	33.3
Establishing		3.5	25			3.5	28					
Recognizing	12.5	3.5		3.9	12.5	3.5	14		12.5	55.6	12.5	
Draw		17.2				17.2					12.5	
Solve			6.3	3.9			14	6.3			12.5	
Indicate	18.9		6.3		18.9				18.9			
Distinguish		3.5	6.3	3.9		3.5						
Describe	6.3			3.9	6.3			6.3	6.3			
Define		3.5		3.9		3.5				11.1		
Construct				3.9				12.5				
Show		3.5				3.5						
Inquire	6.3				6.3				6.3	11.1		
Argue				3.9								8.3
Extract		3.5				3.5						
Read		3.5				3.5						
Determine		3.5				3.5						
Propose		3.5				3.5						

used the verb identify and explain. The verb identify belongs to the lowest category of cognitive processes namely to remember. This verb means locate knowledge in long-term memory that fits with the material presented while the word explain belongs to the second category of cognitive processes. These processes are about constructing meaning from information received to bring up the causes and effect model.

Level 2 is similar in both scientific sections but it is completely different in the arts section. In the scientific sections, curriculum authors use the same action verbs namely the verb explains and identify. In this level, curriculum authors rarely use other action verbs such as determining which belong in this category and apply the verb propose which represents the highest category of cognitive process (called creating, designating assembling the elements to form something new and coherent, or make an original production). For the second level of the arts section, the action verb used often is recognize which belongs to the lowest category of cognitive processes.

In the 3rd level of scientific sections curriculum authors still use the word frequently, however, in the art section, instead they use the verb identify. In the 3rd level curriculum authors introduce the word resolve in genetic chapters this verb can be categorized apply: run or use a procedure in a given situation

In the level 4 or baccalaureate curriculum authors are very interested in explaining the mechanisms and phenomena in physiology and immunity, solving genetic problems and giving arguments in favor of the theory of evolution. The verb argue only appears in the chapter on biological evolution. This verb is rarely used; it belongs to a high cognitive level: Evaluate which encourages students to make judgments based on criteria and standards. Based on this analysis, we can conclude that curricula authors use in almost all of the chapters taught, verbs belonging to a low cognitive level.

The taxonomy of educational objectives is a classification system that provides an organizational structure and gives meaning commonly understood objectives classified in one of its categories, improving communication

Table 3a. Distribution of specific objectives of sciences section according to the Revised Bloom's Taxonomy (%).

			Cognitive process dimension																		
			Remember		Understand							Apply		Analyse			Evaluate		Create		
			1.1	1.2	2.1	2.2	2.3	2.4	2.5	2.6	2.7	3.1	3.2	4.1	4.2	4.3	5.1	5.2	6.1	6.2	6.3
Knowledge dimension	Factual	Aa.	13.3			1.2			3.6		25.3	2.4									
		Ab.	2.4						1.2												
	Conceptual	Ba.	13.3			2.4	2.4		4.8		1.2										
		Bb.							1.2	1.2											
		Bc.							1.2	1.2	9.6						1.2				
	Procedural	Ca.										1.2									
		Cb.	3.6								3.6	1.2									
		Cc.										1.2									
	Metacognitive	Da.																			
		Db.																			
		Dc.																			

(Krathwohl, 2002). Indeed, the three double-entry taxonomy tables show the distribution of learning objectives according to the Revised Bloom's Taxonomy, respectively, of the Science section (Table 3a), the Math section (Table 3b) and the Arts section (Table 3c).

For the three sections studied each specific objective has two dimensions: first, the cognitive process category, as shown in the table columns by subcategories of 1.1 to 6.3. And on the other by the category knowledge represented in Aa lines to Dc. Such an objective is found only in a single table cell.

Specific objectives are unevenly distributed in the table of taxonomy in the three analyzed curricula. The activities recommended by the curriculum authors of the three curriculum primarily concerns the explication of mechanism or biological or geological phenomenon and identifying a structure or a phase of a phenomenon. Firstly, both belong to the category of factual knowledge regarding the basic elements that students need to know about the life sciences and earth. Secondly, two belong to the less complex cognitive process; those to remember which mean retrieving relevant knowledge from long-term memory and understand meaning determining the meaning of instructional messages, including oral, written, and graphic communication. A third type of activity recommended for students belongs to procedural knowledge. In this case students are seeking the Interrelationships among the basic elements. Within a larger structure that enable them to function together in order to determine the classifications and categories. Any time this third category lowest cognitive process: the recognition of these classes and these categories.

It is noted that curriculum authors ignore the more complex cognitive processes: analyzing, evaluating and creating. The majority of the targets are mainly in the category to remember and understand.

Regarding the dimension of knowledge, the new revised taxonomy of knowledge category that is metacognitive knowledge is completely absent in the Tunisian official programs. The types of the most cited knowledge is factual and conceptual knowledge.

In Tunisian programs life science and earth, there was a net increase in the weaker cognitive processes (e.g. remember). This could be due to the concentration of curriculum authors on the scientific content more than the development of

Table 3b. Distribution of specific objectives of maths section according to the Revised Bloom's Taxonomy (%).

			Cognitive process dimension																		
			Remember		Understand							Apply		Analyse			Evaluate		Create		
			1.1	1.2	2.1	2.2	2.3	2.4	2.5	2.6	2.7	3.1	3.2	4.1	4.2	4.3	5.1	5.2	6.1	6.2	6.3
Knowledge dimension	Factual	Aa.	10.6			1.5			6.1		22.7	3									
		Ab.	1.5						4.6	1.5	3										
	Conceptual	Ba.	22.7				1.5		1.5		3	1.5									
		Bb.																			
		Bc.									7.6										
	Procedural	Ca.										1.5									
		Cb.	4.6		1.5																
		Cc.																			
	Metacognitive	Da.																			
		Db.																			
		Dc.																			

Table 3c. Distribution of specific objectives of arts section according to the Revised Bloom's Taxonomy (%).

			Cognitive process dimension																		
			Remember		Understand							Apply		Analyse			Evaluate		Create		
			1.1	1.2	2.1	2.2	2.3	2.4	2.5	2.6	2.7	3.1	3.2	4.1	4.2	4.3	5.1	5.2	6.1	6.2	6.3
Knowledge dimension	*Factual*	Aa.	22.6		1.9				1.9		15.1	1.9									
		Ab.	3.8						1.9		1.9										
	Conceptual	Ba.	24.5				1.9		1.9		3.8										
		Bb.																			
		Bc.							1.9		5.7										
	Procedural	Ca.										1.9									
		Cb.	5.7									1.9									
		Cc.																			
	Metacognitive	Da.																			
		Db.																			
		Dc.																			

other skills. On the knowledge dimension Conceptual and Procedural items predominated.

CONCLUSION AND IMPLICATION

The Tunisian curriculum of life sciences and earth development essentially advocates the building of skills in the cognitive domain at the expense of the other capabilities of the affective domain and psychomotor. The cognitive processes and knowledge are focused on the lower levels of knowledge and skills. The majority of learning objectives are grouped in the conceptual dimensions and understanding or below these levels. This suggests that there is a barrier because it is a mobile obstacle to block access to the higher categories of skills in learning the life and earth sciences between the third and the fourth category of cognitive process. In addition, there were no learning objectives in the dimension of metacognitive knowledge. Knowing that metacognition is the mental process of thinking about own thoughts; the ability to assess and evaluate his or her thinking.

Almost everyone agrees that one of the main goals of education, regardless of level, is to help develop thinking skills, including critical thinking skills Gelder (2005). Curriculum authors can promote critical thinking by creating environments where learners can dare to be critical thinkers.

The authors are in agreement with the idea recommended by Behar-Horenstein and Niu (2011) to exchange the instructions to students committed to the higher thinking model. The same explicit instruction in critical thinking needs to be included in the curriculum because studies have shown that improving students' critical thinking are more likely to occur when teaching skills thesis is explicit (Behar-Horenstein and Niu, 2011).

It seems that curriculum authors ignore more complex cognitive processes in the design of curricula: analyze, evaluate and create. The majority of objectives are mainly in the category to remember and understand. In addition, metacognitive knowledge is completely absent despite its importance. So, rewriting the curriculum is strongly recommended for more consistency and not focusing on the first two categories of the revised taxonomy. The purpose of this rewriting is to develop students' critical thinking skills along with their life and earth sciences. Finally, further studies can evaluate the corrected curriculum and its impact on students. In my opinion the authors of curricula ignore the importance of developing critical thinking they must cooperate with researchers in didactics of life and earth sciences to be better trained.

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