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GRAPHING SKILLS: CONSTRUCTION DIFFICULTIES AND LEARNING PROCESS IN LIFE AND EARTH SCIENCES AMONG SECONDARY SCHOOL LEARNERS (MOROCCO)

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ABSTRACT Graphs are commonly used to represent mathematical functions, data from life and earth sciences and to illustrate scientific phenomena and play an important role in teaching scientific concepts. However, in high school, learners have difficulties to translate numerical data into visual presentations. At the beginning of the school year, diagnostic assessment allows to evaluate the learners' graphing skills and to identify the parts of the graph on which learners have difficulties. The diagnostic evaluation focused on graphical construction skill allowed us to detect the gaps of the high school learners and proposing some pedagogical tools to help them to improve their graphical construction skills; that play an important role in teaching different concepts of life and earth sciences.

Our results showed that girls represent 63.13% of the learners assessed, the majority (63.59%) of participants is from first year high school (TC) aged between 14 and 16 years. Learners in high school baccalaureate (Bac) represent only 36.4% of learners assessed and aged between 17 and 20 years. Almost a quarter of the TC learners did not complete the required graph and 7% of the learners drew only the axes and 34.61% of the learners inverted them. The graduations are presented according to the scale in 64.78% realization and according to the order of the table in 35.21% of learners' graph. The textual parts are present in 73% of the realization and a large number of learners (62.17%) did not present the scale on the graph.

The majority of learners do not have the necessary skills to establish all elements of the graph. In this work, we propose pedagogical tools (mnemonic models, method sheet, etc.) that will allow a better organization of graphic teaching in primary, secondary and even high schools and make graphs cognitively available to learners.

KEYWORDS: Didactic, graphing, learning process, graph characteristics, life and earth sciences.

I. INTRODUCTION

Morocco, like most countries in the world, has adopted the competency-based approach, which aims to make students able to solve problem situations by mobilizing an integrated set of resources acquired over the course of a specific learning (MEN). Indeed, at the end of their secondary education, learners must master, in addition to a core of disciplinary knowledge, scientific skills and communication skills. These skills allow at learner to express using mathematical and scientific languages (MEN). The language of science is a synergistic integration of words, diagrams, pictures, graphs, maps, equations, tables and other forms of visual and mathematical expression [1-5].
The ability to construct and interpret graphs is a central aspect of science and critical for developing knowledge and reasoning process of learners [6-10]. Cromley et al. [11] showed that instruction of construction and graphical reasoning ameliorates knowledge as well as these skills transfer to new domains. Moreover, representing the phenomenon graphically appeals to memorization, in particular procedural memory and helps learners to understand scientific data and facilitates the conceptualization of some phenomena [11-14]. Constructing and interpreting graphs play a key role in understanding scientific data, in learning mathematics and problem solving, although the lack of these competences has proved to be a handicap and a limiting factor in the learning of scientific concepts [3, 15-17].

The Life and Earth Sciences curriculum indicates that students should be able to construct, analyze and interpret graphs and identify relationships among variables [18-19]. However, learners have difficulties in translating numerical data into visual presentations and interpreting them using scientific language [20-22]. These difficulties are not only related to the parameters to be presented in the graph but also influenced by how these parameters interact with learners' knowledge, causing cognitive confusion about the purpose of the graph and how it should be written [23,24]. Also, it is possible that the learners perceive the graphing as a simple translate data into visual presentations and they don't understand that graphing data is a reorganization of data to reveal the relationship between the variables [25].

At the beginning of the school year, diagnostic assessment allows to evaluate the learners' graphing skills and to identify the parts of the graph on which learners have difficulties. Therefore, teachers can understand the reasoning processes that learners use when constructing graphs and know the misconceptions, thus they be able to help learners to better understand graphs. The goal of this research is to evaluate and understand the difficulties of creating graphs of high school students. Thus, to propose a process pedagogic adapted to the different obstacles encountered by these learners and pedagogical tools allowing to acquire this skill which plays a primordial role in secondary education, particularly in life and earth sciences.

II. METHODOLOGY

The diagnostic evaluation was carried according to the notes of the Ministry of National

Education, Preschool and Sports at the beginning of the school year (from October 2 to October 9, 2021). It was conducted in five classes of TC and three classes of 2BAC. A total of 217 assessments were collected.

The learners must trace graphically the variation of species number as function of surface (Table 1).

Table 1. Exercise data

Surface (m^2)	1	4	9	16	25
Number of plant species	11	38	59	71	71

Evaluation grid was used to evaluate the graphical presentations realized. This grid includes the elements of the graph: axes, graduations, curve, points, scale, and arrows.

The statistical analysis is based on descriptive statistics (percentages, means), the tabular and the graphs were made using SPSS software.

III. RESULTS

Table 2 represents the demographic characteristics of the learners participated. Girls represent 63.13% of the learners evaluated, regarding the school level, the majority (63.59%) of the participants are in TC and their age varies between 14 and 16 years. Learners in the 2BAC represent only 36.4% of the learners evaluated and belong to the 17-20 year age group.

Table 2: Demographic characteristics participants (N=217)

Demographic characteristics	**Number**	**percentage%**
Gender		
Male	80	36.86
Female	137	63.13
Age (years)		
14-16	138	63.59
17-20	79	36.40
Education		
Tc	138	63.59
2bac	79	36.40

Our results showed that 71.88% of the learners realized the curve, some learners (TC) did not realize the graph (21.12%) and 7% of the learners drew only the axes (Figure 1).

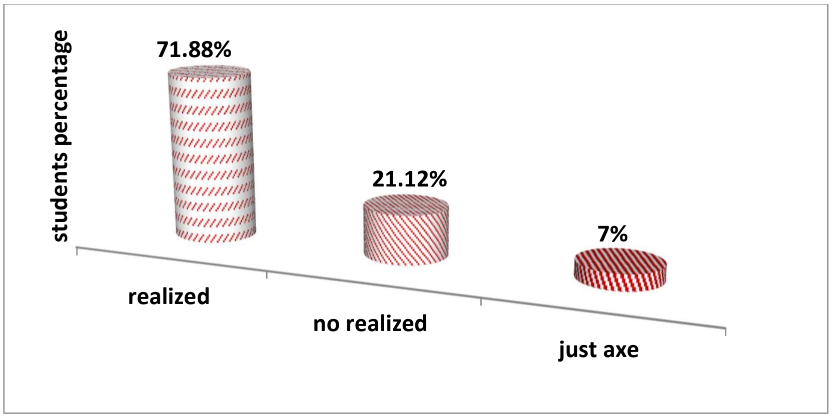


Figure 1: Students Percentage according to graphic realization

Axes of graph

All learners who realized the graph, drew the axes, only 34.61% have reversed them. These axes are all graduated (91.02%), titled in 73.07% presentations and nearly half (58.97%) of the axes are arrowed (Figure 2).

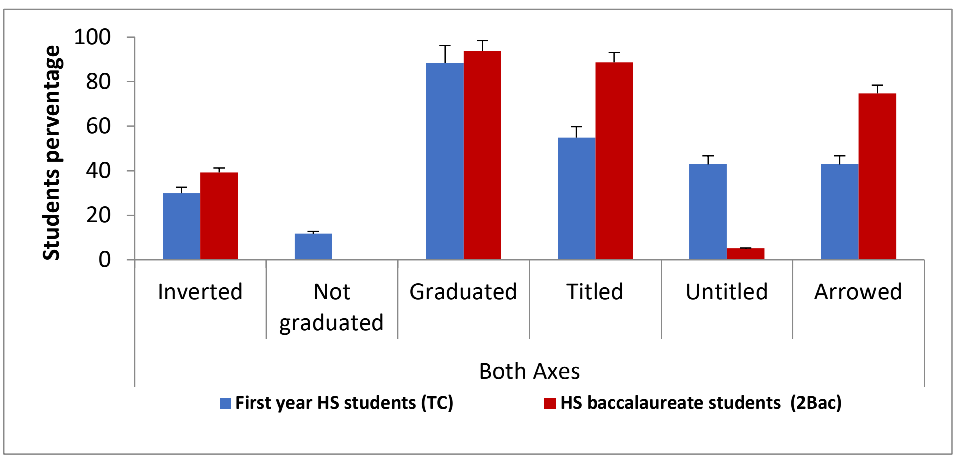


Figure 2 : Students percentage according to axes realization.

Many graphical presentations (73.07%) don't have a title, only 23.71% of the learners put a title to graphs and they placed it at the top of the graph.

Graduations and scale

Graduations are present in 91.02% of realization; they are presented according to the scale in 64.78% presentation and according to the order of the table in 35.21% of learners' realization (Figure 3). A large number of learners (62.17%) did not present the scale on the graphs.

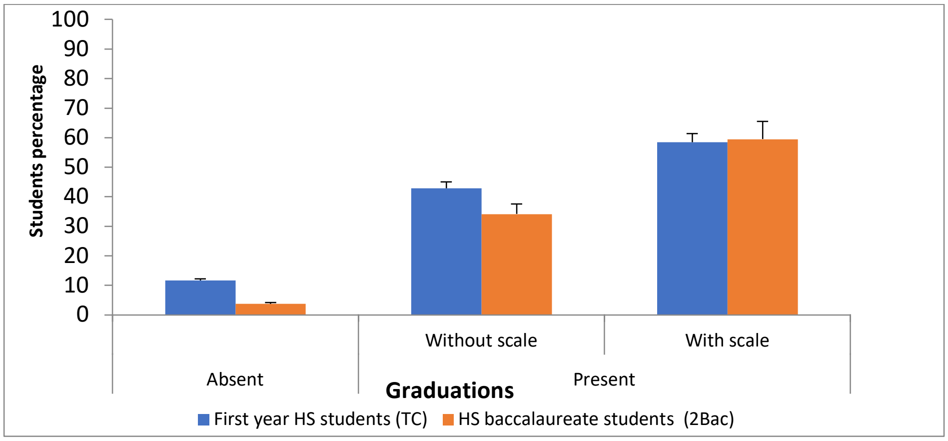


Figure 3: Students percentage according to curve realization.

Curve and points

The points are presented in all realization and the learners placed them respecting the parallelism with the axes. A minority of learners (6.48%) did not trace the curve; whereas the majority of the learners (93.58%) connected the points to trace the curve. 38.35% of learners traced the curve through the zero even though it is not presented in the data.

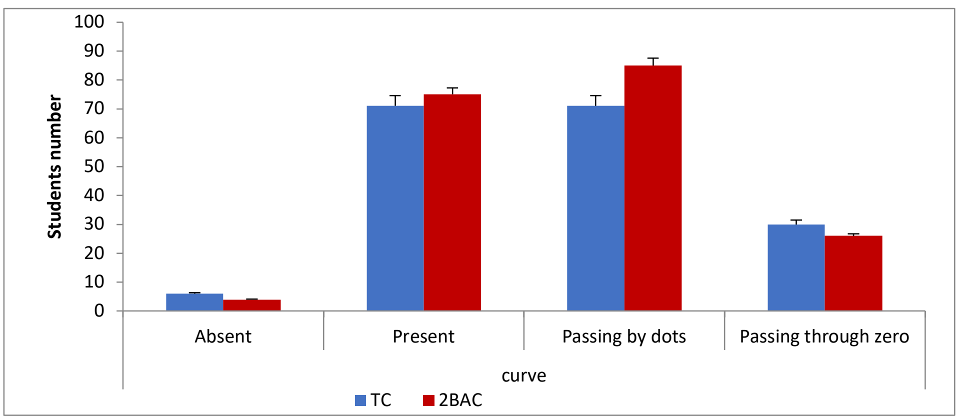


Figure 4: Students percentage according to curve realization.

IV. DISCUSSION

The realization and use of graphs allow a series of analytical operations and gives learners the opportunity to reason about immobile events. According to Amsel and Byrnes [26], symbolic communication influences several levels of cognition, from the lowest, such as perception and memorization, to the highest, such as reflective and metacognitive procedures [27, 28].

The results show that some learners (28.12%) were unable to translate experimental data into a visual presentation, even though they were confronted with this situation in primary and secondary school. Passaro [24] showed that converting data into a visual presentation constitutes a major obstacle for secondary school students; similar problem was reported by Brasell and Budd Rowe [25]. These learners do not make the semantic links between external data (table) and graphical representation, whereas in primary school they studied how to organise data in a table and present it graphically. Most researchers attributed these problems to learners' misconceptions and cognitive deficits [17, 29]. For these learners, the cognitive difficulty seems to be major which makes graphic construction a real problem situation for them, which requires the intervention of the teacher as a mediator to guide these learners to transform data into a graph representation and at the same time, proceeding by shoring in similar didactic situations as a means to foster cognitive skills [30].

Graphical representation is a visual language that is part of the sign system that allows the retention and understanding of scientific concepts [5, 31]. The graphic elements are designated by Bertin [5] as a monosemic system, its elements, or signs, have a single meaning. Consequently, precision on the details of representations develops learners' cognitive clarity and promotes conceptualization [32]. For that, the diagnostic assessment focused on the basic elements of the graph: axis, points, scale, curve, axis labels and title.

The axes representation and scaling not present a problem for learners, but someone between them (34.61%) reversed the axes. These results are different from those of Brion and Fijalkow [33] and Brasell and Budd Rowe [25] where the percentage of inversion is between 42.5% and 48%, so learners confuse between the independent variable which is associated at the abscissa axis and the dependent variable which is associated at the ordinate axis. Therefore, the term "as a function of" constitute a cognitive confusion for some learners which will be a cognitive obstacle during graphical writing-reading [33]. According to Passaro' work [24], 30% of secondary school learners are unable to distinguish between independent and dependent variable.

In general, the presence of arrows at the end of the axes shows that the values are increasing, in our study, almost half of the learners (41.03%) did not arrow the axes. This shows that they have not assimilated the usefulness of the arrows.

Scales are presented in 91.02% of the realization but presented in the order of the table in 35.21% of the presentations. Brion and Fijalkow [33] found that 73.5% of the learners did not represent the data correctly among them 68.4% presented it in table order.

Learners are unable to put a series of numbers in order on a graduated axis, indeed, at the end of primary school they should master the representation of numbers on a graduated axis respecting the given intervals [34, 35]. The participants are unable to mobilize this skill to solve this problem situation (graphic representation). They have a cognitive confusion between the data presented in the table and what it represents, which prevents a good reading and therefore a good understanding of this type of writing (table) which reflected on the reading/writing of the graphs related to it [25, 33]. This leads teachers to reinvest, even in the qualifying secondary class, in exercises that allow learners to find the writing code of the graduations.

The points are present in all the presentations which means that learners have the ability to place the dots in parallel with the axes. These results are different from the results of the studies conducted by Brion and Fijalkow [33] which revealed that 61% of the realizations present the points. The majority of learners (93.58%) has constructed the best-fit line, 11.85% did not draw the curve even though they placed the points correctly. For these learners, the graphical writing only exists through its axes and points, the interest of connecting them is misunderstood. Various authors underline that the curve constitutes an epistemological obstacle to the notion of function [36]. However, in primary and secondary school, learners are taught to draw curves from a table of values from several disciplines (physical sciences, life and earth sciences, geography, etc.) and also to read information on a curve (Textbook). However, at this level, for the learners, these curves do not represent functions since the notion of function is only introduced in first year high school [37]. Generally, the participants are able to draw the curve therefore less shoring is required in this situation.

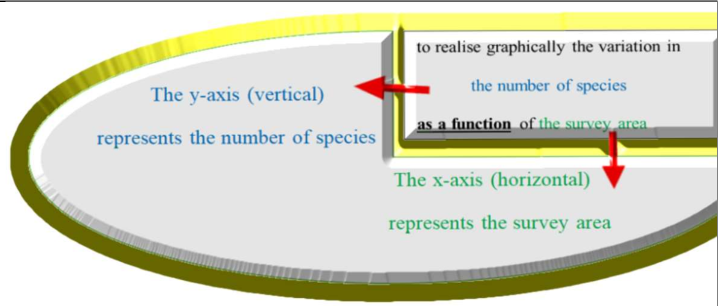
The textual parts of the axes are not represented in 26.93% of realization which differs from the results found by Brion and Fijalkow [33] who found that 53.7% of the drew axes are not legended. Similarly, the general title is absent in 73.1% representation. Learners think that the textual parts are not part of the graphic [33].

At the end of secondary school, the learner should be able to recognise the type of graph to be used, present it (title, legends, axes..) and read the information given on it. However, this study has shown that a large proportion of learners in qualifying secondary education do not have the competence to translate numerical data into a graphical representation. Fijalkow and Brion [33] have shown that group work, the use of a "whole language" and numerous graphic writing-reading confrontations will help develop students' cognitive clarity towards the object of graphic writing. This shoring correct misconceptions involving selection of appropriate axes, determining scales, and assigning data points [10]. As well as an accompanying posture provides punctual help on the learners realization in order to avoid them failing in the face of a new situation [38]. As well as a teacher accompanying posture provides punctual help on the learners realization in order to avoid them failing in the face of a new situation [38].

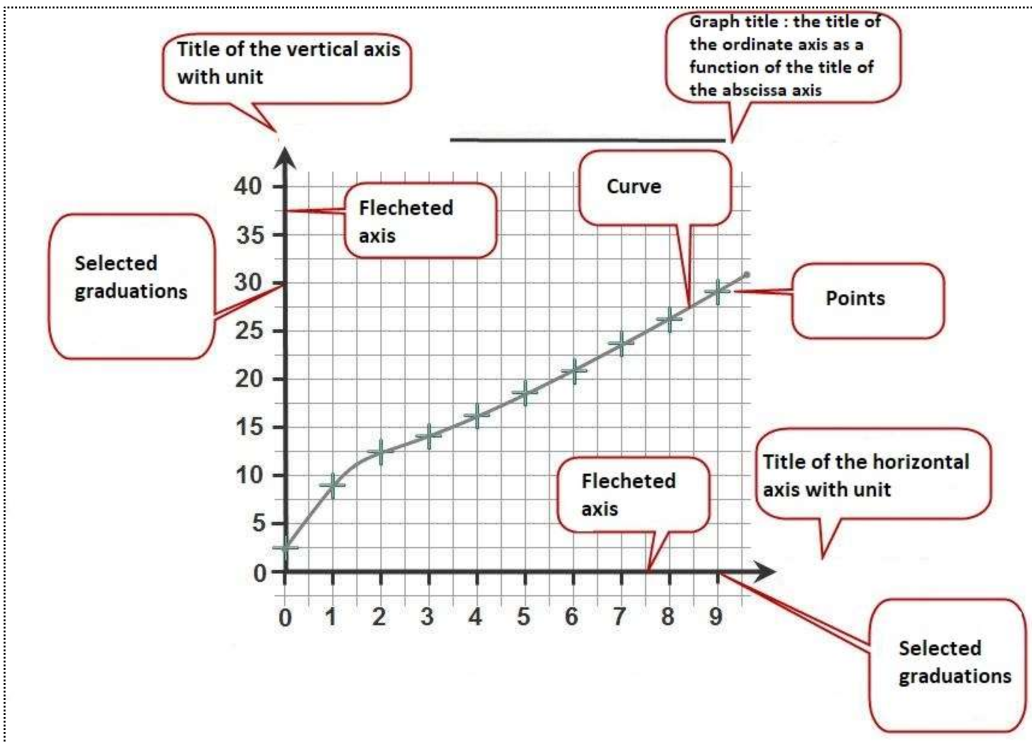
In this work, we propose a learning process that will allow for a better organization of the graphical teaching in primary, secondary schools and even in high school.

- Suggest mnemonics models that might help learners not to confuse the abscissa axis with the ordinate axis.

- Develop learner's cognitive clarity by providing models that differentiate between dependent variables associated with the ordinate axis and independent variables associated with the abscissa
axis.



- Visualize the steps of graphic writing by guiding learners step by step to make method sheets.



- Putting learners in many graphic writing situations where learners have to do elementary tasks in a repetitive way. This will make this type of representation a reflective activity in their learning.

- Use constructive evaluation to monitor learner's acquisition of graphic writing skills.

- Evaluate the learner's ability to mobilize this skill by following an investigative approach where learners realize an experiment, organize the results in a table and then translate them into a graphic representation.

V. CONCLUSION

Our results showed that the majority of learners do not have the necessary skills to establish all the elements of the graph. In addition, the cognitive requirements are increased in terms of understanding such a problem situation. Thus, a radical intervention on graphic perception will increase the cognitive capacity of learners, promote the creation of graphics with more precision and make them cognitively available to learners.

The establishment of a learning process is essential, which includes pedagogical strategies (mnemonic models, method sheet...) to teach this skill and strategies to effectively assess the ability of students to adapt and mobilize this skill according to the problem situations proposed in their course.

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