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Graphic construction: difficulties of Moroccan High School students and learning process

Brahim El Ghmari

braxgh@gmail.com

Karima Mounchid

Research Article

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Abstract

Much research has focused on the difficulties of graph construction and interpretation in mathematics and the physical sciences, but little studies have been carried out in life and earth sciences, despite the importance of this skill in the teaching of scientific concepts. This article evaluates the graphical construction skills of secondary school students (aged 14 and 19) by examining the presence of different graph elements. The results revealed that students are unable to establish all the elements of graphical representation and they have a lack of understanding of the term “"as a function of"”, which constitutes a cognitive obstacle when interpreting graphs. Consequently, the practice of graphical skill (construction and interpretation) should be offered frequently and revisited at different levels in order to promote the creation of graphics with more precision and make them cognitively available to learners. This article proposes a learning process that will make it possible to better organize the teaching of graphical construction in primary and secondary school, and even in high school. Finally, this article suggests pedagogical tools (mnemonic models, method sheets, etc.) to help students improve their graphic construction skills, which play an essential role in teaching of various life and earth science concepts.

Introduction

Graphical representations are commonly used in textbooks to represent mathematical functions, display data from science, represent relationships between variables and illustrate scientific phenomena. They help visualize quantitative data and facilitate understanding scientific phenomena. ((Shah and Hoeffner, 2001); (Roth et al., 1999); (Roth & Bowen, 2001); (Shah & Hoeffner, 2001); (Leinhardt & Steele, 2005); (Mitnik et al., 2009); (Franzblau & Chung, 2012); (Bahtaji, 2020)). According to the OECD, graphic representation is a central concept in learning science and mathematics. Indeed, graphic representations are ideal tools for improving comprehension and stimulating knowledge stored in memory. In addition, graphs enable more effective visual decoding of quantitative information, so they give meaning to this information and facilitate its conceptualization ((Brossard, 2006); (Wu and Krajcik, 2006); (Dupuy-Kuntzmann, 2013); (Vishkurti, 2014); (Binali, 2024)). According to Amsel and Byrnes (Amsel & Byrnes, 2002), symbolic communication influences several levels of cognition, from the lowest, such as perception and memorization, to the highest, such as reflexive and metacognitive procedures ((Matalliotaki, 2010)). Representing graphically requires a series of operations: visual perception, logical thinking, determining the relationship between variables, etc., which enables students to work on several interdisciplinary skills and improves their reasoning process ((Ferreiro, 2001); (Lowe, 2004); (Matalliotaki, 2010); (Uzun et al., 2012); (Busby, 2018); (McHugh et al., 2021)). Although graphics have considerable importance in the learning scientific phenomena, students encounter difficulties in translating numerical data into visual presentations appropriate to a given situation ((Chang et al., 2021); (Shah & Hoeffner, 2001); (Testa et al., 2002); (Kali, 2006); (Roslina et al., 2020); (Bursal & Yetis, 2020)). Berg and Smith (1994) point out that many students lack the mental tools to engage in high-level graph construction or interpretation. As a result, these students will be unable to understand the scientific data as well as the phenomena illustrated by the graphs. For this reason, graphs must not only be present in textbooks, but

must become cognitively available to students. They need to have a good grasp of graphical semiology, which saves them time in perception, and a conscious choice of graph type, which improves their cognitive clarity about the purpose of graphical representations ((Brasell & Rowe, 1993); (Lehrer, R., & Schauble, L., 2022); (Lowrie & Diezmann, 2007); (Roslina et al., 2020)). Many researchers have concluded that graphical construction and interpretation is a very important pedagogical object and that these skills are too important to be left to chance, hence the need for an adequate learning process ((Testa et al., 2002); (Glazer, 2011); (Hipkins, 2011); (Roslina et al., 2020); (Bahtaji, 2020)). Many researchers have focused on graphical representations in mathematics, but little studies have been carried out in the life and earth sciences. In this work, we assessed the difficulties of graphical writing in high school pupils using a diagnostic assessment, the results of which showed that the majority of pupils had not mastered the skills needed to establish all the elements of a graphical representation, and did not distinguish between dependent and independent variables. This led us to propose a learning process pedagogically adapted to the different difficulties encountered by these pupils, as well as the pedagogical tools needed to acquire this skill.

Method

This study involved 217 high school students aged between 14 and 19. The study was carried out at the beginning of the school year, using a diagnostic assessment. Students were asked to transform data presented in a table into a graphical representation. No instructions were given so as not to interfere with or modify their initial representation of the notion of a graph. Assessment of the students' achievements is based on the characteristic elements of the graph: axes, graduations, curve, points, scale, arrows.

Statistical analysis was based on descriptive statistics (percentages, averages), tables and graphs using SPSS software.

Results

The demographic characteristics of the students assessed are shown in Table 1. Girls represented 63.13% of the students evaluated. First year high school (TC) students represented 63.59% of the participants, with ages ranging from 14 to 16 years, whereas high school baccalaureate (2BAC) students represented only 36.4% of the students assessed.

Table 1 : Demographic characteristics participants (N=217).

Demographic characteristics	N	%
Gender		
Male	80	36.86
female	137	63.13
Age (years)		
14-16	138	63.59
17-19	79	36.40
Education		
Tc	138	63.59
2bac	79	36.40

Our results showed that the majority (71.88%) of students drew the curve, 21.12% of First year high school students did not draw the graph and 7% of students drew only the axes (figure 1).

Graph title

Many graphical presentations (73.07%) do not have a general title; only 23.71% of students have given the graphs a title and placed it at the top of the graph.

The axes of the graph

The axes were drawn in all cases, but 34.61% of students inverting them. These axes are almost all graduated (91.02%), captioned in 73.07% presentations and almost half 58.97% of the axes are arrowed (figure 2).

Graduations and scale

Graduations are present in 91.02% presentations; they are presented according to the scale in 64.78% of cases and according to the order of the table in 35.21% of realizations (figure 3). A large number of students (62.17%) didn't show the scale on their presentations.

Curves and points

In all representations, the points were presented and all students positioned them parallel to the axes. Most students (93.58%) connected the points correctly to draw the curve, while a small percentage of students (6.79% (TC) and 5.06% (Bac) did not draw the curve. However, 38.35% drew the curve through zero, even though it is not shown in the data (figure 4). Surprisingly, three students drew an arrow at the end of the curve.

Discussion

Graphics are a coded language created by man to memorize, understand and communicate information (Bartin, 2005). Many researchers have shown that students have difficulty transforming data into visual presentations ((Chang et al., 2021); (Shah & Hoeffner, 2001); (Testa et al., 2002); (Kali, 2006); (Roslina et al., 2020)).

Our results showed that 28.12% of students were unable to convert experimental data into a visual presentation, even if the graph came from their ecology textbook, and they had been confronted with this kind of situation in primary and secondary. According to Downing and Fijalkow (Downing and Fijalkow, 2016), these students don't make the semantic links between tabular data and graphical representation, even though in primary school they studied how to organize data in a table and present it graphically. (Brion and Fijalkow, 2016.) explain this difficulty by the fact that the two pieces of writing are treated separately. As a result, these students have a high cognitive difficulty that makes graph construction a real problem situation, requiring teacher intervention to bring students to cognitive clarity.

To optimize the graphical translation of data effectively, students need to know the elements of graphical semiology. According to (Lehrer, R., & Schauble, L., 2022), precision in the details of representations promotes conceptualization and develops students' cognitive clarity. To this end, our diagnostic assessment focused on the basic elements of graphing: axis, points, graduations, scale, curve and legends.

The representation of the axes and their graduation posed no problem for the students, but some (34.61%) inverted the axes. (Brion and Fijalkow, 2016) showed in their study a percentage of inversion of 42.5%. Thus, students do not distinguish between the independent variable associated with the x-axis and the dependent variable associated with the y-axis, so the term “as a function of” constitutes a cognitive confusion for some students which will constitute a cognitive obstacle during graphic writing-reading ((V. Passaro, 2009); (Brion and Fijalkow, 2016)). (A. Passaro & Starita, 2008), has shown that 30% of high school students are unable to distinguish between the two variables.

The presence of arrows at the end of the axes shows that the values are increasing. In our study, almost half the students (41.03%) didn't arrow the axes. This shows that they have not assimilated the language of graphics, nor the usefulness of the elements of graph. According to (Bertin, 2005), signs have a predetermined and unique meaning, i.e., a monosemic system, so mastering semiology saves perception time, minimizes loss of information and enables an appropriate choice of graph type.

Graduations are present in 91.02% of representations, but are arranged according to chart order in 35.21% of presentations. (Brion & Fijalkow, n.d.) observed that 73.5% of pupils did not represent the data correctly, 68.4% of whom arranged them according to the order of the table. By the end of primary school, students should have mastered the representation of numbers on a graduated axis, respecting the given intervals. However, the participants in this study were unable to mobilize this skill to solve this problem situation (graphical representation). They have a cognitive confusion between the data

presented in the table and what they represent, which hinders the comprehension of this type of writing (table) which has repercussions on the reading/writing of the graphs linked to it (Brion & Fijalkow, n.d.). Teachers need to reinvest these notions, even at high level, by proposing exercises that enable students to rediscover the conventions of writing graduations.

All students were able to place points parallel to the axes. These results differ from those of (Brion & Fijalkow, n.d.), who found that only 61% of students were able to write the points. The majority of students (93.58%) connected the points to form the curve, 11.85% did not draw the curve even though they positioned the points correctly. For these students, graphical writing exists only through its axes and points, and the importance of connecting them is poorly understood (Schneider, 1990). Although, in primary and high school, students learn 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. However, for students at this level, these curves do not represent functions (Coppé et al., 2006), since the notion of function is only introduced in the first year high school.

The textual elements make the graphical representation understandable on its own, without explications, and they help readers to understand and quickly grasp the information in the graph. The textual elements of the axes are not represented in 26.93% of cases, which differs from the results found by (Brion & Fijalkow, n.d.) who found that 53.7% of plotted axes are not captioned. Similarly, the general title is absent in 73.1% of representations. Students seem to consider that textual parts are not part of graphic writing and assume that everyone can understand what they have presented graphically (Brion and Fijalkow, 2016).

By the end of high school, students should be able to choose the type of graph to use, present it (title, legends, axes) and read the information it contains. On the other hand, this study showed that a large proportion of high school students have not mastered the skill of translating numerical data into graphical representations. (Brion and Fijalkow, 2016) have shown that group work and numerous confrontations of graphical writings can contribute to developing cognitive clarity vis-à-vis graphical realization. And a supportive posture, offering occasional assistance to students in their realizations, can also help them avoid failure in the face of new situations (Bucheton & Soulé, 2009).

Our results have shown that the majority of students have not mastered the skills needed to establish all the elements of a graphical representation, and do not distinguish between dependent and independent variables, and on which axis each variable should be associated. A radical intervention aimed at improving graphical perception could therefore increase students' cognitive capacity and promote the creation of graphs with greater precision. In this context, we propose a learning process aimed at better organizing the teaching of graphical representation not only in primary and middle school, also in high school.

- Suggest mnemonic models to help students distinguish abscissa from ordinate.

- Develop students' cognitive clarity by proposing models that differentiate between dependent variables associated with the ordinate axis and independent variables associated with the abscissa axis.
- Place students in numerous graphical writing situations where they have to perform elementary tasks in a repetitive manner. This will make this type of representation a reflexive activity in their learning.
- Visualize the steps involved in graphic writing, guiding students step-by-step to create method sheets.
- Use constructive assessments to monitor students' acquisition of graphic writing skills.
- Assess pupils' ability to mobilize this skill by following an investigative approach in which they carry out an experiment, organize the results in a table, then transform them into a graphic representation.

Conclusion

Our investigation found that the majority of the learners possess the fundamental skills that would allow them to create all aspects of a graph. The gap that exists in their participation in graphical representation is an area of major concern in the understanding and solving of various problems in the real world and in academics. The training to achieve such goals should be well-organized and systematic in character. This learning should consist of evidence-based teaching strategies geared toward strengthening their comprehension of graphs. For example, models can remind students of the principal steps and principles for building a graph.

A method sheet, as another resource, provides clear step-by-step instructions to build specific types of graphs. Additional interactive assignments such as guided practice or collaborative problem-solving problems can strengthen and help apply the skills of learning and practicing the skills. Therefore, assessment must be done to find out how the students would adjust their graphing skills to solve problems. Traditional assessment has gone too far; it has to be moved to performance-based tasks that would simulate situations that might occur in a real-life context in students' coursework. This kind of assessment is good to determine the competencies a student has and can give guidance in case of deficiency for the proper application and use of those skills in different situations.

With integrated instructional strategies and effective assessments, teachers can create an appropriate climate for learning where the learners can build, review, and apply their graphing skills confidently. In this way, it will guarantee that not only do learners possess the technical skills to build a graph, but they also develop the problem-solving abilities and critical thinking essential for success in school and, subsequently, in life.

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Figures

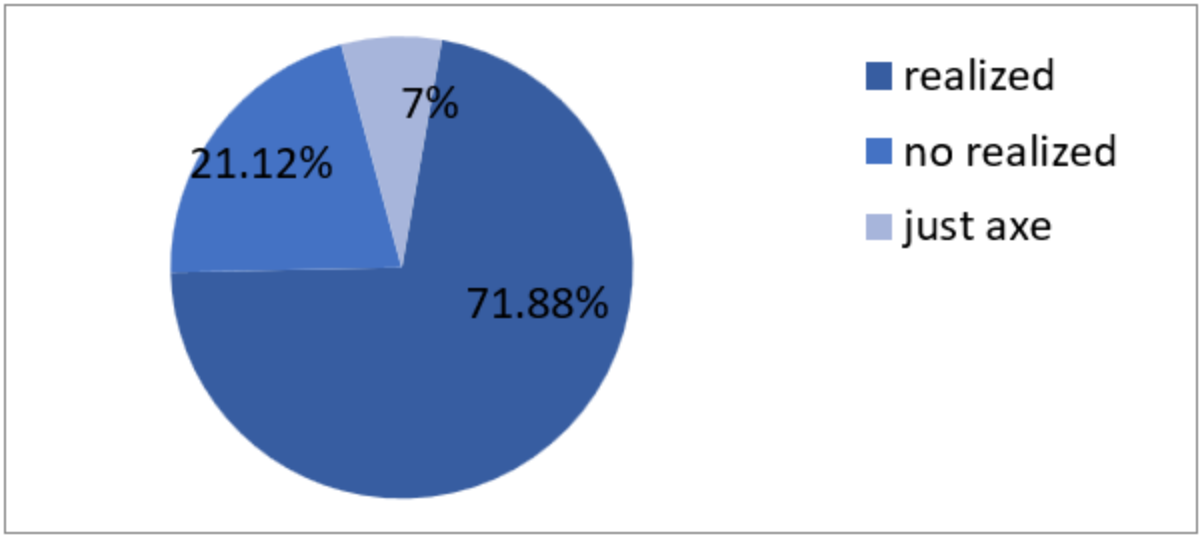


Figure 1

Students Percentage according to graphic realization.

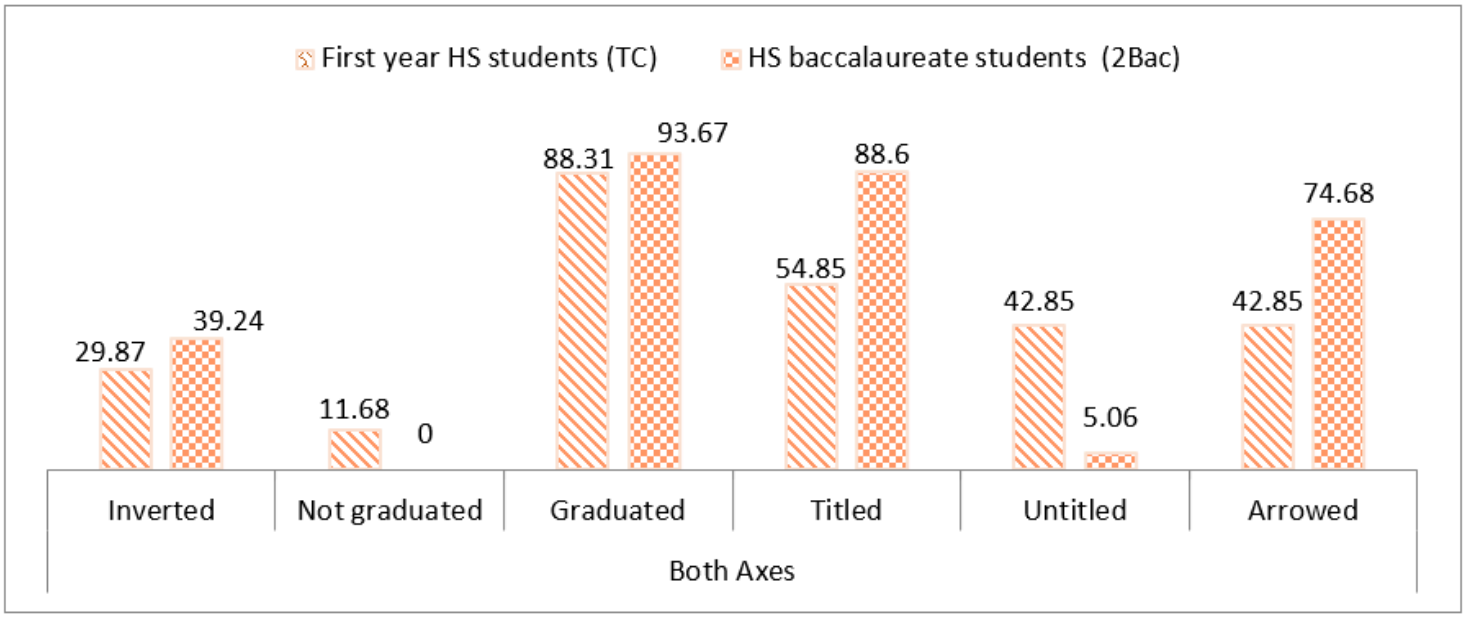


Figure 2

Students percentage according to axes realization.

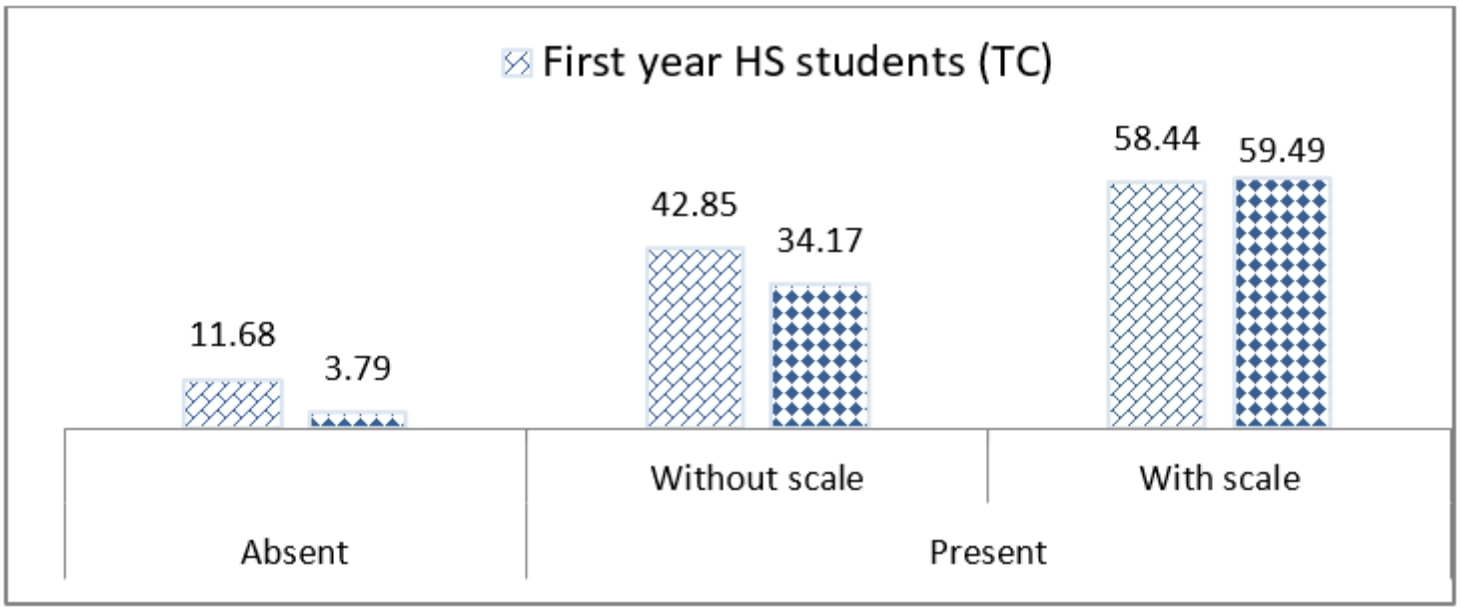


Figure 3

Students percentage according to graduations realization.

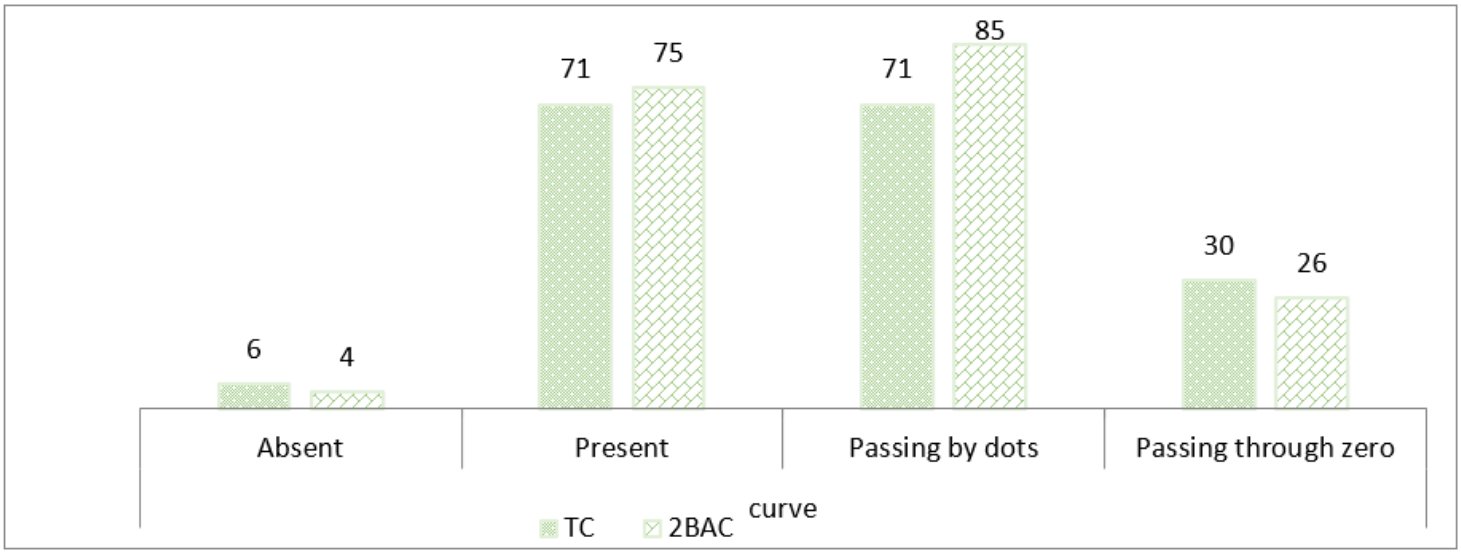


Figure 4

Students percentage according to curve realization.