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# Reading levels in the activities related to statistical graphs in Costa Rica textbooks

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*In this paper we present results of analysing the reading levels, according to the model proposed by Curcio and collaborators of statistical graphs in Costa Rica compulsory education textbooks. The activities linked to statistical graphs included in three complete textbooks series in each of the primary (grades 1 to 6) and secondary education (grades 7 to 9) were analysed.*

*Keywords: Statistical graphs, reading levels, textbook analysis, compulsory education.*

## Introduction

Statistical graphs are essential for communicating information in many different areas, and appear frequently in the media, and for this reason a minimal statistical literacy is needed for the citizen to be able to interpret these graphs critically (Weiland, 2017). This need is still more urgent in the current pandemic situation, where citizens need to understand statistical information mainly distributed in graphs to collaborate with political and health authorities (Batanero et al., 2021). Moreover, graphical competence is part of statistical literacy defined by Gal (2002) as the ability to interpret and critically evaluate statistical information, data-related arguments, or stochastic phenomena, which they may encounter in diverse contexts, joined to the ability to discuss or communicate reactions to such statistical information, when required (pp. 2-3).

Consequently, graphical competence is a main goal in school curricula in many countries. This is the case of the compulsory education curricula in Costa Rica (MEP, 2012) that, for primary education recommend that children are requested to collect and record data to answer statistical questions about themselves and their environment, using bar and line graphs, tables and pictograms, as well as to read and interpret these representations since the 1st grade. Further study of graphs is accomplished in secondary education, where histograms, frequency polygons and pie charts are also introduced with the aim of improving students' graphical abilities. These goals can only be achieved with a correct teaching of the topic and the use of adequate textbooks.

Research analysing different content in textbooks is increasing today, since these books are a main didactical tool for teachers and students and constitute an intermediate stage between the official curricular guidelines and the teaching implemented in the classroom (Fan et al., 2013). Consequently, the aim of this research was to analyse the activities where statistical graphs are used in the Costa Rica textbooks and, more specifically the reading levels required from the students to complete these activities.

Below we describe the foundations, method and results of the research and we finish with some considerations to improve the teaching of statistical graphs in compulsory education.

## Foundations

The work is supported, in the first place, by theoretical models on difficulty levels in reading graphs, and secondly on some research that have previously studied statistical graphs in primary school textbooks which is used to compare with our results.

### Reading Levels of Graphs

A graph is a complex semiotic object, due to the different components that need to be comprehended in order to fully understand the information displayed (title, scales, types and amount of data and graphical elements used to represent the data). The graphic builder encodes the information represented by means of these elements and the reader of the graphic should carry out a series of interpretative processes for each of these components and for the graph as a whole as well as of the relationship of the graph with the information context (Arteaga & Batanero, 2011; Sharma, 2006; Spence, 1991).

Consequently, the interpretation of a graph is more or less complex, depending on the information that needs to be extracted from the graph and for this reason, several authors have defined levels in the reading of graphs. These levels reflect the fact that on the same statistical graph, we can raise questions of different levels of difficulty, which can refer to the title and scales, the variables and values being represented, the interpolation or extrapolation of values, and even to the detection of biases in the graph or in statements based on the graph. In this research, we relied on those defined by Curcio and his collaborators (Friel et al., 2001; Shaughnessy, et al. 1996; Curcio, 1989):

- L1. Reading the data*, where only the literal reading of a graph element is requested, for example, reading the graph title, the scale labels or the frequency for a given value.
- L2. Reading between the data*. Besides the literal reading of the graph, in this level the child has to compare various data represented in the graph or complete some arithmetical calculations with the data.
- L3. Reading beyond the data*. This level involves a generalization of the values in the graph, for example, interpolating or extrapolating the information displayed.
- L4. Reading behind the data*. A person attains this level when he or she is able to make a critical valuation of the graph, of the way it has been constructed or can discuss a statement related to the graph content.

### Previous research

We also draw on other research that analyses statistical graphics in primary school textbooks, most of which only dealt with primary education textbooks. Díaz-Levicoy in various works analyses statistical graphs in primary school textbooks (primary education Chilean and Spanish textbooks in Díaz-Levicoy et al. (2016), grades 4 to 6, Argentinean textbooks in Díaz-Levicoy et al. (2017), Peruvian textbooks in Díaz-Levicoy et al. (2018)), with very similar conclusions. The authors study the type of graph proposed, the activity requested of the child, and the reading levels required in the activity. They conclude that bar graphs are most frequently used, with little weight given to other

types of graphs in the curriculum. The most frequent activity in Spanish textbooks is reading graphs, while calculating was predominant in the Chilean books.

The most frequent reading levels in Curcio's (1989) classification were L1 followed by L2 in Chile and Spain; L2 being the most common level in Argentina. Level L3 appears from 4<sup>th</sup> grade in Spain and 3<sup>rd</sup> grade in Chile, and is not proposed in Argentina textbooks. As regards L4 only grades 5 and 6 in Spain and grades 4 and 6 in Argentina consider this level. The tendency was different in the Peruvian textbooks, where half activities in grade 1 correspond to level L1 and the remaining to L2, which predominates in all the other grades with very scarce activities in levels L3 or L4,

A direct precursor to this work is that by Jiménez-Castro et al. (2020), who analysed statistical graphs and reading levels in the activities related to them in two series of primary school textbooks (grades 1 to 6 in Costa Rica). Bar and line diagrams (single and multiple), pie charts, dot plots and pictograms were observed, with a large predominance of bar charts. Generally, the reading level required in the activities was L2 level.

All the above research deals with primary education textbooks and only that by Jiménez-Castro et al. (2020) was carried out in Costa Rica. This paper expands research by Jiménez Castro et al. (2020) with the analysis of a new editorial (6 new books) and expand the study with an investigation of three complete editorials for secondary education (grades 7 to 9, additional 18 textbooks) with particular focus on the reading levels requires in the activities proposed for statistical graphs in these textbooks. Below we describe the method, present the analysis categories and discuss the results. We conclude with some implications for the teaching of statistical graphs.

## **Method**

This is a qualitative research, based on content analysis, which was carried out through the following phases (Porta & Silva, 2003):

- Fixing the object of analysis: In each textbook, the activities that incorporate statistical graphs were studied.
- Determining the categories or coding rules: The categories were the reading levels identified a priori based on previous research (Friel et al., 2001; Shaughnessy, et al., 1996; Curcio, 1989)
- Checking the reliability of the coding-categorisation system: the coding was reviewed several times by one author and discussed with other colleagues until an agreement on the coding was reached. These categories are presented in section called “Analysis categories”.

The information of the variable “Reading level” was coded, following an inductive and cyclical process; a detailed reading of each activity was carried out, the data obtained were interpreted and reviewed to make sense of the analysis, the data were related to the defined categories. This process was carried out of one of the authors of the paper as part as his doctoral thesis, consulted with the director of the doctoral thesis and with other colleagues, to give greater validity to the study.

### **Sample of textbooks and activities**

The sample includes all the activities related to statistical graphs (activities where statistical graphs appear or activities that propose to build a statistical graph) in three books series of primary education

(grades 1 to 6, 18 textbooks) and in another three series of textbooks directed to secondary education (grades 7 to 9, 18 additional textbooks). All the editorials were selected because they are most widely used in Costa Rica and are listed in the Appendix. In total, the number of activities analysed were 579 activities in primary education and 363 in secondary education.

### Analysis categories

We used the reading level required, using the classification by Curcio (1987), and Friel et al. (2001). Below we include examples of activities classified in each of these levels:

*L1. Reading the data:* At this level the activity concentrates on answering questions about the frequency of a value for a variable (or the value to which a frequency corresponds), without going so far as to make other connections or perform other calculations with the data. An example is shown in Figure 1, where children should complete a bar graph to represent the frequency of a series of objects (previously classified) shown in an image.

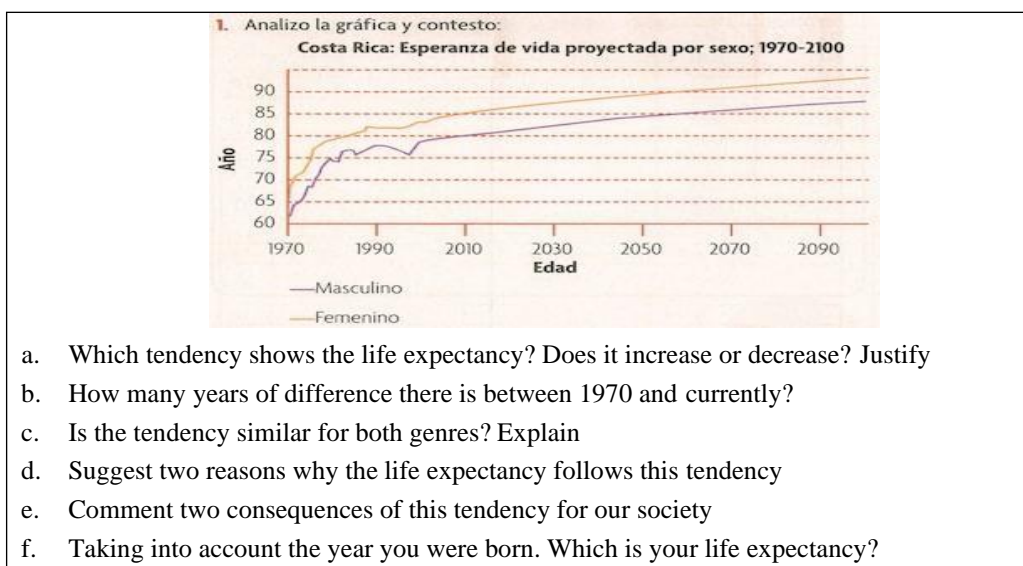


**Figure 1. Example of reading level L1 “reading the data” (Source S1, p. 298)**

*L2. Reading between the data:* this level applies when comparisons or operations must be made with the data obtained from a graph in order to solve the activity. It involves identifying relationships between the data, as in questions b of the activity presented in Figure 2, where, after reading the data, operations have to be performed on the data. Question f also corresponds to this reading level, because depending on the year of birth, the student must locate such data on the graph, and if the year is not a multiple of 10, he/she needs to locate it on the X-axis in order to identify the life expectancy corresponding to that year.

*L3. Reading beyond the data:* This reading level is achieved in activities where we ask to obtain data not explicitly represented within the graph, which includes interpolating or extrapolating a piece of data on the graph. We classify questions a and c in Figure 2 at this level as well, as the trend is not explicitly represented but must be inferred from reading the values on the graph and comparing along the time axis.

*L4. Reading behind the data.* The solution of activities qualified at this level require from the solver a critical appraisal of the method of data collection, validity, or reliability or to justify the conclusions made. Although this level of reading is not common in textbooks, we have encountered some examples in activities such as the one presented in question d in Figure 2, where the student is asked to think about the reasons explaining the increase in life expectancy along time.



**Figure 2: Task reproduced from AL5 p. 166**

## Results and discussion

In Table 1 we present the percentage of activities that were classified in each of the reading levels defined by Curcio and his collaborators (Friel et al., 2001; Shaughnessy, et al., 1996; Curcio, 1989) by school grade. We can observe the predominance of level L1 (reading the data), where only a literal reading of the data displayed in the graph is required from the students in the first three grades, in particular in the first grade, where the children are only starting to be introduced to some statistical ideas. This level diminishes in relevance since grade 4 in favour of upper reading levels.

**Table 1: Percentage of tasks by reading level and school grade**

Reading levels	Primary education						Secondary education		
	1st (n=50)	2nd (n=108)	3rd (n=97)	4th (n=109)	5th (n=93)	6th (n=122)	7th (n=176)	8th (n=82)	9th (n=105)
L1	68.0	42.6	44.3	24.8	22.6	32.8	21.0	30.5	29.5
L2	30.0	43.5	40.2	52.3	52.7	50.8	59.1	52.4	46.7
L3	2.0	7.4	6.2	16.5	16.1	7.4	13.6	15.9	10.5
L4		6.5	9.3	6.4	8.6	9.0	6.3	1.2	13.3

The reading level L2 (reading between the data, where students are also requested to perform some computations or comparisons with the data in the graph) was very frequent along all the school grades, including secondary education. It was the most frequent level in grades 4 to 9 because in these levels' graphs are also used to facilitate the computation of central tendency and spread measures and for this reason, the students are requested not only to read the graph but to compute mean, mode, range or other statistics with the data represented in the graph. Interpolation and extrapolation activities (reading level L3), as well as critical reading activities (Level L4) appear with low frequency in all the grades, although they are a bit more frequent in secondary education.

These results contrasts with what is reflected in the study described by Díaz-Levicoy et al. (2016), where Spanish and Chilean books remain only at reading level L1 in the first two grades and is still

the most frequent level along all the primary education. In Costa Rica, reading levels 3 and 4 appear significantly from the second year onwards and increase in frequency until the sixth year. In the Spanish context, the maximum reading level only appeared in the fifth grade, whereas in the Chilean context, it is incorporated in a sustained manner from the fourth grade onwards, coinciding with the recommendations given in NCTM (2000) to promote the making of inferences and the obtaining of predictions from the data analysed. In Argentina, L3 is not taken into account and L4 only in grades 4 and 6. So, the distribution of reading levels in primary education in our research is more similar to that in the Peruvian textbooks, where half activities in grade 1 correspond to level L1 and the remaining to L2, which predominates in all the other grades with very scarce activities in levels L3 or L4.

In Table 2 we analyse the reading levels of the activities analysed by editorial, and we can observe some differences. As regards primary education, AL present more than half the activities in the L2 reading between data level, which suggest a stronger emphasis in computation in this publisher. EV is the editorial with less activities in this level, while it put more weight in L1 reading the data, in order to reinforce in the children, the learning of the different graphs before going further in more complicate activities. All the three editors include a small percentage of L3 and L4 activities which are those promoting statistical reasoning in dealing with predicting variables not in the graph and reinforcing the critical reading of the information.

**Table 2: Activities with different reading levels in the various editorials**

Reading levels	Primary education			Secondary education		
	AL (n=147)	EV (n=181)	SA (n=251)	PI (n=126)	PO (n=92)	SA (n=145)
L1	27.2	47.0	34.3	31.7	33.7	15.2
L2	54.4	40.3	46.2	58.7	41.3	57.9
L3	8.8	5.5	13.5	7.1	13.0	18.6
L4	9.5	7.2	6.0	2.4	12.0	8.3

As regards secondary education, SA is the editor with less L1 reading the data activities, which are less important at these teaching levels, given the age of students. PO is the publisher with less L2 activities, implying a smaller emphasis in computation. This is the editorial with a more balanced distribution of reading levels in the activities, since it includes more than a 10% of activities in each of the levels L3 and L4.

## Conclusions

In this paper we present the analysis of the reading levels collaborators (according to the model by (Friel et al., 2001; Shaughnessy, et al., 1996; Curcio, 1989) required to complete the activities linked to statistical graphs contained in the most widely used textbooks in Costa Rica, at primary and secondary school levels.

The study reveals a predominance of the first two levels “reading the data” where only a direct reading of the information in the graph is required and “reading between the data”, where only comparisons or computation with that information is needed. Specifically, this second level is predominant in most

grades even at secondary education level, which suggest an excessive emphasis in developing the computational abilities, instead of focusing in fostering their statistical literacy or reasoning.

We particularly point to the scarceness of level L4 “reading behind the data” activities, which will be particularly relevant in the education of secondary school students. These activities serve to develop in the student their ability to reason with statistical information, to discuss arguments based in statistics information and to assess the reliability of such information and in this way, help improving the students’ statistical literacy.

Also note that the L3 level in secondary school textbooks is not much considered, this type of level requires the student to be able to perform interpolations and extrapolations of the data presented in a graph, which is considered an important part of graph comprehension (Friel et al., 2001)

We suggest that especially in secondary education, it would be important to incorporate a greater number of L3 and L4 activities, which are closely related to the skills necessary to develop good statistical literacy levels (Gal, 2002)

As we pointed out in the previous sections, there are scarce research examining statistical graphs in secondary school education textbooks, and therefore this research should be continued with the analysis of other variables and textbooks in other countries. However, we hope our research make teachers conscious of the importance of taking into account all the possible reading levels when working with statistical graphs at school and help them organise teaching to take into account this didactical variable.

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## **Appendix: List of editorials used in the analysis**

### **Primary education textbooks**

- Serie 1: *Asociación Libros para Todos (AL)*. Textbooks directed to grades 1 to 6 published in 2017.
- Serie 2: *Editorial Santillana Serie Casa del Saber (SA)*. Textbooks directed to grades 1 to 6 published in 2016.
- Serie 3: *Editorial Eduvisión. Visión Matemática (EV)*. Textbooks directed to grades 1 to 6 published in 2014.

### **Secondary education textbooks**

- Serie 1: *Editorial Publicaciones Innovadoras en Matemáticas (PI)*. Textbooks directed to grades 7 to 9 published in 2017.
- Serie 2: *Editorial Publicaciones Porras y Gamboa (PO)*. Textbooks directed to grades 7 to 9 published in 2017.
- Serie 3: *Editorial Santillana (SA)*. Textbooks directed to grades 7 to 9 published in 2017.