



HAL
open science

Statistical Graphs Semiotic Complexity, Purpose and Contexts in Costa Rica Primary Education Textbooks

Maynor Jiménez-Castro, Pedro Arteaga, Carmen Batanero

► **To cite this version:**

Maynor Jiménez-Castro, Pedro Arteaga, Carmen Batanero. Statistical Graphs Semiotic Complexity, Purpose and Contexts in Costa Rica Primary Education Textbooks. Eleventh Congress of the European Society for Research in Mathematics Education (CERME11), Utrecht University, Feb 2019, Utrecht, Netherlands. hal-02411599

HAL Id: hal-02411599

<https://hal.science/hal-02411599>

Submitted on 15 Dec 2019

HAL is a multi-disciplinary open access archive for the deposit and dissemination of scientific research documents, whether they are published or not. The documents may come from teaching and research institutions in France or abroad, or from public or private research centers.

L'archive ouverte pluridisciplinaire **HAL**, est destinée au dépôt et à la diffusion de documents scientifiques de niveau recherche, publiés ou non, émanant des établissements d'enseignement et de recherche français ou étrangers, des laboratoires publics ou privés.

Statistical Graphs Semiotic Complexity, Purpose and Contexts in Costa Rica Primary Education Textbooks

Maynor Jiménez-Castro¹, Pedro Arteaga² and Carmen Batanero³,

¹Universidad de Costa Rica, Costa Rica; maynorjc@correo.ugr.es

²Universidad de Granada, Spain; parteaga@ugr.es

³Universidad de Granada, Spain; batanero@ugr.es

The aim of this research was analyzing the way in which statistical graphs which are introduced in the new curricular guidelines for Costa Rica primary education are introduced in the textbooks, and compare the results with previous research in other countries. We analyze the distribution of the graph complexity, purpose and context in 167 activities related to statistical graphs selected from the two most widely used textbooks series. Results suggest a non-uniform distribution in both series and suggest ways to enhance the activities proposed in the textbooks.

Keywords: Statistical graphs, reading level, semiotic complexity, textbooks, primary education.

Introduction

Statistical graphs are a main tool to represent information in the media and professional life and acquiring graphical competence is needed for citizens to manage in the information society. This need led Costa Rica to increase the relevance of statistical graphs in the primary education (M.E.P, 2012), following suggestions such as those of the GAISE project (Franklin, Kader, Mewborn, Moreno, Peck, Perry, & Scheaffer, 2007). More specifically, statistical graphs are included in the Costa Rica curriculum in Primary Education as follows:

- In second grade, bar graphs are introduced, with the main objective that the student makes a simple reading of the information and in third grade, the students are expected to construct such graphs and interpret them, using the mode, maximum and minimum.
- In the fourth grade, the student must interpret information in dot plots and it is proposed to incorporate the spreadsheet as a support tool in graphic representations.
- In the fifth grade, pie charts are included and in the sixth, the line graphs to visualize trends in data series. The graphic comparison of two or more data groups is also suggested.

These goals can only be achieved with a correct teaching of the topic and the use of adequate textbooks. There are however no available empirical studies providing evidence that Costa Rica textbooks follow these guidelines. The aim of this paper is to analyze the graphs included in Costa Rica textbooks and use this information to help teachers to organize the teaching of the topic.

Background

Theoretical framework

Statistical graphs are complex semiotic objects, as suggested by Bertin (1967), who remarked that interpreting a graph requires first the isolated interpretation of each element, such as the title or

scales and finally as a global interpretation of the whole graph. Moreover, Arteaga and Batanero (2011) analyzed the semiotic activity involved in the construction of graphs by prospective teachers, and suggested that different graphs may vary in semiotic complexity, according to the mathematical objects needed in this process. Specifically, the authors described four semiotic levels in statistical graphs that will be used in our analysis:

- S1. Representing isolated data. Graphs classified in this level only represent some isolated data without considering the whole set from which the data were extracted.
- S2. Representing a list of data one by one without any attempt to building a distribution. The list of data or a data set is represented in the same order in which the data are located in the list with no use of the numerical order. There is no grouping of similar values of the variable or computation of frequencies. Consequently, although in this graph the idea of variable is used, the distribution is absent. In Figure 1 we present an example.



Figure 1: Example of graph of semiotic complexity S2 (Source: S4, p. 278)

- S3. Representing a data distribution. These graphs include the representation of a distribution, with values and frequencies for each value; For quantitative variables, the order of the variable values in the graph axes (if used) is the ordinary numerical order (see figure 2)



Figure 2: Example of graph of semiotic complexity S3 (Source: A5, p. 146)

- S4. Representing several distributions on the same graph. At the highest level more than one distribution is represented on the same graph. (an example is given in Figure 3)



Figure3: Example of graph of semiotic complexity S4 (Source: S6, p. 263)

Following ideas by Kosslyn (1985), we also considered statistical graphs as a resource that can be used with different purposes:

- *Analysis*; when the main goal is using the graph to identify or discover many features that are hidden in the unorganized data set; for example discovering the mode or the asymmetry of the distribution.
- *Communication*; when the graph is used to transmit to another information about the data and its relationships in an efficient way.
- *Construction*; in traditional teaching, an additional purpose is providing procedures to help students learn how to build a correct graph.

Another aspect analyzed is the context of the graph, using the classification established in the PISA studies, which is described in OECD (2016), where it is suggested that the mathematical performance of an individual can be influenced by the context in which he develops his problem situation. In this sense, the context in which the collection, organization and representation of the data are circumscribed may affect the understanding of the graph. This classification contemplates the following contexts:

- *Personal context*: corresponds to situations in the scope of personal activities of the child, his family or peer group. An example of this context is presented in Figure 3, where the graph shows the activities preferred by a group of boys and girls.
- *Social context*: these contexts correspond to the problems where aspects of the social sphere are addressed, beyond the personal life of the child; for example, the neighborhood, or city. They can correspond to voting systems, public transport, government, public policies, demography, publicity, national statistics or economy. Gambling is also included in this context because it is widely used in society.
- *Labor or school context*: consist of those situations where the problem addresses aspects of the world of work: school, work, employment, production, sale, etc.
- *Scientific context*: this context is related to problems in the field of science and technology, and includes aspects such as: climate, ecology, medicine, space science, genetics, etc.

Previous research

Research analyzing 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 (Herbel, 2007). The textbook selected usually provides the main basis why the topic is taught (Shield & Dole, 2013).

Our research is based in other studies that analyzed statistical graphs in the textbooks in other countries, in particular, Díaz-Levicoy, Batanero, Arteaga and Gea (2016), who analyzed the statistical graphs included in three series of Spanish textbooks and three other Chilean series of Primary Education, and compared their results with the curricular orientations. The authors studied the type of graph, level of semiotic complexity, and reading levels implicit in the activity. They conclude the greater presence of the bar chart with little weight of other graphs included in these curricula. Regarding the level of reading, the most frequent were the intermediate ones.

Method

For this study, the curricular orientations referring to the education of statistical graphs in Costa Rica have been analyzed, as well as the two most frequently used series of books in Costa Rica; Asociación Libros para Todos (AL) and Editorial Santillana (S), using content analysis. The sample of publishers was directed or not probabilistic, because we selected the textbooks most spread in the schools of the country (see Appendix). A total of 167 different graphs were analyzed and classified according to the following variables:

- *Semiotic complexity level*: Arteaga and Batanero (2011) observed in their study as a higher semiotic level in the graphs constructed by a sample of prospective teachers implied a higher level of reading of them by the prospective teachers. Therefore, semiotic levels are related to the reading levels of a graph, that is an important ability related to good levels of graphical competence (Wu, 2004).
- *Purpose of the graph*: Cazorla (2002) shows that statistical graphs are an instrument of both data analysis and information transmission, for all this, considering Kosslyn's ideas we classify the graphs according to their purpose.
- *Context of the graph*: Monteiro and Ainley (2007) observed how the interpretation of the graphs mobilizes knowledge and feelings that affect their understanding and how the context of the graph influences the interpretation of it, showing the importance of considering the context of the graphs when interpreting them.

Each graph was analyzed according to these three variables, Maynor, one of the authors of this paper, classified the different graphs as part of his PhD studies, and this process was supervised by the other two authors. The variables analyzed on this paper were previously used in different studies carried out by Díaz-Levicoy and published in relevant national and international journals (Díaz-Levicoy et. al, 2016, Díaz-Levicoy, Giacomone and Arteaga, 2017).

Results

Graph semiotic complexity

Overall the most frequent semiotic complexity level was level 3 (see Table 1) since, 67.7% of the graphs represented a distribution; 24.0% of graphs represented a data list (level 2) and only 8.4% corresponded to the highest level of semiotic complexity, representing two or more distributions in the same graph. In the AL editorial, the percentage of activities at level 2 and level 4 was 10.7%, in

contrast to 78.6% of activities classified at level 3. Similarly, at the S editorial, 62.2% of the activities were classified as level 3 and 30.6% and 7.2% as level 2 and 4, respectively.

This general data coincide with the results obtained from the semiotic analysis of the graphs in Díaz-Levicoy et al. (2016), where 58.6% of graphs analyzed corresponded to level 3. However, the second most frequent semiotic level proposed in the Spanish study was level 4 with 22.3%, while in Costa Rican textbooks it is level 2 with 24.0%. Contrary to the Spanish study's results, in the Costa Rica textbooks since the highest level of semiotic complexity (S4) represents only 8.4% of graphs.

Semiotic Complexity	AL (n=56)	S (n=111)
S2	10,7	30,6
S3	78,6	62,2
S4	10,7	7,2

Table 1: Frequency and percentage of graphs according semiotic complexity and editorial

Regarding the distribution of semiotic complexity by school year, in Table 2 we show the increment of semiotic complexity with school grade. In the first grade only level 2 activities were found, while in the sixth grade graphs in all the semiotic complexity levels are proposed. Moreover, in grades 2 to 5, complexity level 3 is dominant and only in the 6th grade the most common graphs are those of level 4. In Díaz-Levicoy et al. (2016) research, semiotic complexity level 4 graphs are included from grade 2, and are the most common semiotic level at fifth and sixth grades. This includes a clear difference in the way in which activities are addressed in Spanish and Costa Rican textbooks, where representations of several distributions on the same graph are scarce in Costa Rica.

Semiotic Complexity	School grade					
	1 (n=8)	2 (n=44)	3 (n=26)	4 (n=33)	5 (n=28)	6(n=28)
S2	100	29,9		15	13,6	27
S3		70,1	100	76,2	86,4	29,7
S4				8,8		43,2

Table 2: Percentage of graphs by semiotic complexity and school grade

Purpose of the graph

The graph is considered according to Kosslyn (1985), as a resource that is used for analysis, communication and in traditional teaching, for purely constructive purposes. This variable has not been taken into account in previous research, so our results represent an original contribution. The activities analyzed in the textbooks tend to use the graphs for analysis purpose with 60.7% of the total graphs used for this purpose, while only 24.4% are used for communication purposes, as shown in Table 3. The constructive purpose does not seem to be so relevant to both publishers and only represents 15% of the total of activities analyzed.

When analyzing the results by grade (Table 4), we observe that that the most common purpose in the first grade is communicating information and little analysis and graph construction are encouraged. In the remaining grades, the purpose of analysis predominates, although there is always an interest in graphic construction, in particular until grade 3. This variable has not been taken into account in previous investigations.

Purpose	AL (n=56)	S (n=111)
Analysis	58,7	61,8
Communication	21,7	25,9
Construction	19,6	12,4

Table 3. Frequency and percentage of graphs according purpose and editorial

Purpose	School grade					
	1 (n=8)	2 (n=44)	3 (n=26)	4 (n=33)	5 (n=28)	6(n=28)
Analysis	18,8	42	63,6	69,1	69,1	77
Communication	62,5	39,8	12,7	19,8	14,7	17,5
Construction	18,8	18,2	23,6	11,1	16,2	5,4

Table 4. Percentage of graphs by purpose and school grade

4.3 Contexts

The contexts of graphs are summarized in Table 5, where the most common context used in AL is primarily the school /workplace while in S both this context and personal contexts involve 33, 3%, of the activities each. Both publishers point strongly to the school / work context and to a lesser extent to scientific situations.

Context	AL (n=56)	S (n=111)
Personal	3,6	33,3
Social	28,6	18,9
School /work place	48,2	33,3
Scientific	19,6	14,4

Table 5. Frequency and percentage of graphs according context and editorial

The relationship of the context with school grade is shown in Table 6, where the School/work place context dominates along second to the fifth grades, mainly due to situations related to school. In the first year, personal and social contexts are more frequent, in coincidence with Mingorance's research (2014) while social and scientific contexts are more frequent in the sixth grade. Scientific context is scarce in the first school years, but increases after the fourth grade.

Context	School grade					
	1 (n=8)	2 (n=44)	3 (n=26)	4 (n=33)	5 (n=28)	6(n=28)
Personal	37,8	31,8	26,9	21,2	7,1	21,4
Social	37,5	18,2	34,6	21,2	7,1	28,6
School /work place	25,0	38,6	34,6	36,4	64,3	21,4
Scientific		11,4	3,8	21,2	21,4	28,6

Table 6. Percentage of graphs by context and school grade

Conclusions

The two series of books analyzed, concentrate their activities at the semiotic complexity level 3 that is in the representation of a data distribution in coincidence with Díaz-Levicoy et al. (2016) results.

The results of the analysis showed that the main goal of graphs in the textbooks is analysis, followed by communication with only 18% graphs oriented only to learn how to build the graph. In our opinion more activities oriented to build a graph should be included because previous literature show the importance of graph construction as part of a good graphical competence (Wu, 2004) and because this ability is recommended in Costa Rica's curricular guidelines (M.E.P., 2012). There were also variation between the different grades with personal contexts more frequent in first grade and educational context more frequent in grades 2 to 5. In grades 1 to 3 scientific contexts hardly appear, while starting from grade 4 they constitute about a quart of all the graphs.

These results are useful for teachers who should take into account the relevance of variables as semiotic complexity, purpose and context in statistics education and select adequate activities when introducing their students to statistical graphs, because previous research show the importance of taking into account these variables in the teaching of statistical graphs (Arteaga and Batanero, 2011, Cazorla, 2002, Monteiro and Ainley, 2007, Díaz-Levicoy et al., 2016)

Textbooks are a teaching and learning resource with an important tradition within the classroom, because they provide support to teachers and students throughout the instructional process. It is therefore necessary to study how the textbooks present statistical topics as a first step to suggest possible improvement in their content and to check that they follow the curricular guidelines.

Project EDU2016-74848-P and group FQM126 (Junta de Andalucía).

References

- Arteaga, P., & Batanero, C. (2011). Relating graph semiotic complexity to graph comprehension in statistical graphs produced by prospective teachers. In Proceedings of *CERME 7*. (Vol. 7, pp. 725–734). Lyon; ERME.
- Bertin, J. (1967). *Semiologie graphique*. Paris: Gauthier-Villars.
- Cazorla, I. (2002). *A relação entre a habilidades viso-pictóricas e o domínio de conceitos estatísticos na leitura de gráficos*. Doctoral Dissertation. Universidad de Campinas.

- Díaz-Levicoy, D., Giacomone, B. y Arteaga, P. (2017). Caracterización de los gráficos estadísticos en libros de texto argentinos del segundo ciclo de Educación Primaria. *Revista Profesorado*, 21(2), 300–326.
- Díaz-Levicoy, D., Batanero, C., Arteaga, P. y Gea, M.M. (2016). Gráficos estadísticos en libros de texto de Educación Primaria: Un estudio comparativo entre España y Chile. *BOLEMA. Boletim de Educação Matemática*, 30(55), 713–737.
- Franklin, C., Kader, G., Mewborn, D., Moreno, J., Peck, R., Perry, M. y Scheaffer, R. (2007). *Guidelines for assessment and instruction in statistics education (GAISE) report: a pre-k–12 curriculum framework*. American Statistical Association.
- Herbel, B. A. (2007). From intended curriculum to written curriculum: Examining the "voice" of a mathematics textbook. *Journal for Research in Mathematics Education*, 38(4), 344–369.
- Kosslyn, S. M. (1985). Graphics and human information processing. *Journal of the American Statistical Association*, 80(391), 499–512.
- M.E.P. (2012). *Programa de estudio matemáticas, I, II y III Ciclos de la educación general básica y ciclo diversificado*. San José, Costa Rica: Ministerio de Educación Pública.
- Monteiro, C. y Ainley, J. (2007). Investigating the interpretation of media graphs among student teachers. *International Electronic Journal of Mathematics Education* 2(3), 188-207.
- OECD. (2016). PISA 2015 assessment and analytical framework: Science, reading, mathematics and financial literacy. Paris: OECD.
- Shield, M. & Dole, S. (2013). Assessing the potential of mathematics textbooks to promote deep learning. *Educational Studies in Mathematics*, 82(2), 183–19.
- Wu, Y. (2004, Julio). Singapore secondary school students' understanding of statistical graphs. *10th International Congress on Mathematics Education*. Copenhagen, Dinamarca.

Appendix: Books analyzed

- AL1. Calderón, Y. (Ed.) (2017) *Matemática 1*. San José, Costa Rica: Asociación Libros para Todos.
- AL2. Calderón, Y. (Ed.) (2017) *Matemática 2*. San José, Costa Rica: Asociación Libros para Todos.
- AL3. Calderón, Y. (Ed.) (2017) *Matemática 3*. San José, Costa Rica: Asociación Libros para Todos.
- AL4. Calderón, Y. (Ed.) (2017) *Matemática 4*. San José, Costa Rica: Asociación Libros para Todos.
- AL5. Calderón, Y. (Ed.) (2017) *Matemática 5*. San José, Costa Rica: Asociación Libros para Todos.
- AL6. Calderón, Y. (Ed.) (2017) *Matemática 5*. San José, Costa Rica: Asociación Libros para Todos.
- S1. Santillana. (2016). *Matemática 1*. San José, Costa Rica: Author
- S2. Santillana. (2016). *Matemática 2*. San José, Costa Rica: Author
- S3. Santillana. (2016). *Matemática 3*. San José, Costa Rica: Author
- S4. Santillana. (2016). *Matemática 4*. San José, Costa Rica: Author
- S5. Santillana. (2016). *Matemática 5*. San José, Costa Rica: Author
- S6. Santillana. (2016). *Matemática 6*. San José, Costa Rica: Author