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Statistical Graphs in Natural and Social Sciences Textbooks in Chile

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ABSTRACT

Background: Currently, statistical graphics are an interdisciplinary resource for the development of various activities, such as mathematics, natural sciences and history, geography, and social sciences, being essential for the teaching process. **Objective**: To analyse activities related to statistical graphs in natural sciences and history, geography, and social sciences textbooks in Chilean primary education. **Design**: Qualitative methodology, descriptive level, using the content analysis method. **Setting and participants**: The sample consisted of two textbook collections for both subjects (n=24), covering elementary school courses from grades 1 to 6. **Data collection and analysis**: Through content analysis, types of graphs, reading levels, levels of semiotic complexity, and types of tasks and activities with statistical graphs. **Results**: The results show a total of 105 activities. In natural sciences, reading level 4, semiotic level 3, and the explaining task predominated. In the case of history, geography and social sciences, level 1, semiotic level 2, and the example task predominate. **Conclusions**: More activities must be included in the HGSSci in the first years of schooling, as they only appear in the 5th and 6th grades, especially if analysis work is encouraged. NSci textbooks include some graphs to be addressed in mathematics in later subjects, so we suggested working the graphs systematically within the subjects.

Keywords: Textbook, Statistical graphs, Natural sciences, Social sciences.

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Gráficos estadísticos en libros de texto chilenos de Ciencias Naturales y Sociales

RESUMEN

Contexto: Actualmente, los gráficos estadísticos son un recurso interdisciplinario para el desarrollo de diversas actividades, tales como Matemática, Ciencias Naturales e Historia, Geografía y Ciencias Sociales, siendo esenciales para el proceso de enseñanza. **Objetivo**: analizar las actividades relacionadas con gráficos estadísticos en libros de texto de Ciencias Naturales e Historia, Geografía y Ciencias Sociales de Educación Primaria chilena. **Diseño**: metodología cualitativa, de nivel descriptivo y se utiliza el método de análisis de contenido. **Entorno y participantes**: La muestra estuvo formada por dos series de libros de texto para ambas asignaturas (n=24), contemplando los cursos de 1º a 6º grado de primaria. **Recopilación y análisis de datos**: Mediante el análisis de contenido, tipos de gráficos, niveles de lectura, niveles de complejidad semiótica y tipo de tarea, de actividades con gráficos estadísticos. **Resultados**: Los resultados arrojan un total de 105 actividades. En Ciencias naturales, la predominancia del nivel de lectura 4, el nivel semiótico 3 y la tarea de explicar. En el caso de Historia, Geografía y Ciencias Sociales predomina el nivel 1, el nivel semiótico 2 y la tarea de ejemplo. **Conclusiones**: Es importante incorporar una mayor cantidad de actividades en HCGS en los primeros años de escolaridad, debido a que aparecen únicamente en 5° y 6°, sobre todo si se fomenta el trabajo de análisis. En CN, aparecen gráficos que se proponen para ser trabajados explícitamente en Matemática en cursos posteriores, por lo que se sugiere trabajar los gráficos de manera sistemática entre asignaturas.

Palabras clave: Libro de texto, Gráficos estadísticos, Ciencias naturales. Ciencias sociales.

Gráficos estatísticos em livros chilenos de Ciências Naturais e Sociais

RESUMO

Contexto: Atualmente, os gráficos estatísticos são um recurso interdisciplinar para o desenvolvimento de diversas atividades, como matemática, ciências naturais e história, geografia e ciências sociais, sendo essenciais para o processo de ensino. **Objetivo:** Analisar as atividades relacionadas com gráficos estatísticos em livros didáticos de ciências naturais e história, geografia e ciências sociais do ensino fundamental chileno. **Design**: Metodologia qualitativa, nível descritivo, com o uso do método de análise de conteúdo. **Cenário e participantes**: A amostra foi composta por duas séries de livros didáticos para ambas as disciplinas (n=24), contemplando os cursos de 1ª a 6ª série do ensino fundamental. **Coleta e análise de dados**: Através da análise de conteúdo, tipos de gráficos, níveis de leitura, níveis de complexidade semiótica e tipo de tarefa e de atividades com gráficos estatísticos. **Resultados**: Os resultados mostram um total de 105 atividades. Em ciências naturais, predominou o nível de leitura 4, o nível semiótico 3 e a tarefa de explicar. No caso da história, geografia e ciências sociais, predominam o nível 1, o nível semiótico 2 e a tarefa de exemplo. **Conclusões**: É importante incorporar um maior número de atividades no HGCS nos primeiros anos de escolaridade, pois elas aparecem apenas na 5ª e 6ª séries, principalmente se o trabalho de análise for incentivado. Nas CN, existem gráficos que se propõem a serem explicitamente trabalhados em matemática em disciplinas posteriores, pelo que se sugere trabalhá-los de forma sistemática entre disciplinas.

Palavras-chave: Livro didático, Gráficos estatísticos, Ciências naturais, Ciências sociais.

INTRODUCTION

Statistical skills and knowledge are an inherent necessity in the information society today. The so-called statistical culture is essential in forming citizens, given that we are surrounded by statistical information, which we must interpret correctly to favour adequate decision-making in various daily life situations (Del Pino & Star, 2012). For example, in this context, the media use various statistical graphs to present massive information in small spaces (Arteaga et al., 2011; Cavalcanti et al., 2010). Statistical graphs play a crucial role in data organisation, description, and analysis; it is an instrument of transnumeration –obtaining new information from a data set by changing the representation system (Wild & Pfannkuch, 1999).

In Chile, and following international trends, statistics study in general and statistical graphs in particular begin in the first years of elementary education (from 6 years old), as established in the curricular bases of the Ministry of Education (MINEDUC, 2018). In this context, statistical graphics are configured as interdisciplinary elements for the development of various activities in some subjects such as Mathematics, Natural Sciences (NSci) and History, Geography, and Social Sciences (HGSSci) (Arteaga, 2011; Pino et al., 2014). In this sense, the literature points out that reading and preparing statistical tables and graphs are essential for teaching and learning some contents and concepts in NSci and mathematics (e.g., García et al., 1997). In the case of sciences, they are used as a connection between experimental data, scientific formalisations, and the analysis of the variables that intervene in the different natural phenomena (Arteaga et al., 2011), allowing visualisation in these processes of concepts and abstract relationships that are difficult to understand (Postigo & Pozo, 2000). In this regard, the Organization for Economic Cooperation and Development (OECD, 2017), through the Program for International Student Assessment (PISA), recognises the importance of statistical graphs in empirical research in science, both conceptually and procedurally, being one of the essential scientific competencies that students must develop.

Likewise, in the HGSSci study, statistical graphs are part of the range of images or illustrations that fulfil an informative function that allows for the development of analysis skills and complex historical thinking (Seixas & Morton, 2013), thus constituting an essential element for understanding social processes (Pino et al., 2014). An example is the thematic maps, conceived not only as a representation of spatial concepts but also as an instrument for storing and organising information that enables its analysis and synthesis. In addition, it favours decision-making and the stimulation of rational thinking (Gago et al., 2012).

In the Chilean curriculum, the teaching of statistical graphics is approached in the subject of Mathematics, and using these representations in NSci and HGSSci is offered through learning objectives (MINEDUC, 2018).

In Mathematics, statistical graphs are specific, and their study is stipulated in the thematic axis data and probabilities that organise the syllabus from the 1st to 6th grades of elementary school. This axis responds to the "students' need to record, classify, and read information arranged in tables and graphs" (MINEDUC, 2018, p. 219) through the progressive study of graphs and tables at all elementary school levels. To achieve these objectives, MINEDUC (2018) establishes that students "know and apply surveys and questionnaires by formulating relevant questions based on their experiences and interests, logging the outcomes and making predictions based on them" (p.219).

Regarding NSci and HGSSci, statistical graphs are subject to the skills developed transversally in the learning objectives set from the 1st to 6th grades of elementary school. In the case of NSci, the scientific skills related to the work with statistical graphs are analysis, measuring, registering, and communication. In HGSSci, it is mainly the analysis and work with sources that start from the 3rd grade (MINEDUC, 2018). All these skills are worked on to promote the various forms of thinking, communication, problem solving, among others, for the development of the research method.

The mathematics curriculum guidelines for working with statistical graphs are considered an agenda for the teaching and use of graphs in other subjects, although this is not always the case. For example, Díaz-Levicoy, Pino, et al. (2016) report that the NSci textbook brings some graphs that have not yet been worked on in Mathematics, making it difficult for students to understand scientific phenomena. Therefore, students must study graphs in the order they should be introduced in the classroom (Ragencroft, 1992), giving consistency between the curriculum guidelines and textbooks.

Following these considerations, this research compares activities with statistical graphs in 1st to 6th-grade elementary school textbooks in Chile for NSci and HGSSci. The interest in analysing textbooks lies in their importance in the educational context for teachers and students. Eyzaguirre and Fontaine (1997) point out that this resource is an educational element specially designed and organised systematically for teaching a topic, with vocabulary, illustrations, contents, and exercises that suit the students.

FUNDAMENTALS

The relevance of textbooks

The pertinence of textbooks lies in several reasons. First, they are considered one of the most used educational resources in the school environment (Braga & Belver, 2016; Güemes, 1994; Jiménez, 2000; Olivera, 2016; Salcedo et al., 2018). Second, it provides didactic support to the teaching (teachers) and learning (students) processes (Ferreira & Mayorga, 2010; Jesús et al., 2013; Naranjo & Candela, 2010). Third, the presence and work with textbooks in schools significantly improve student learning (Eyzaguirre & Fontaine, 1997; McGinn & Borden, 1995) because they have had this resource for a long time, using it at schools and home. Finally, one of the most important reasons is that the textbook is not only an immediate source of information for families but also a means of cultural transmission that favours equity in the most disadvantaged sectors of society (Eyzaguirre & Fontaine, 1997; MINEDUC, sf).

The textbook should reliably represent the guidelines described in the curriculum for the development of learning (Díaz-Levicoy & Roa, 2014; Sáez-Rosenkranz, 2016), so it directly affects the success or failure of its implementation (Cantoral et al., 2015).

In the NSci subject, textbooks offer students opportunities to build their knowledge of the area and develop scientific thinking competencies (Gee, 2003). In this sense, science teaching textbooks mainly offer opportunities to describe and observe various phenomena through data collection and review, which are simple, practical activities (Meneses, 2013). For teachers, the textbook is considered one of the most used resources in curricular content planning (Jiménez, 2000; Martínez-Losada et al., 1999; Sánchez-Blanco &

Valcárcel, 2000), in activities realisation and proposals (García, 1996; Martínez-Losada et al., 2003) and as fundamental pedagogical support in the science teaching process (Solarte, 2010). In the same way, the textbook for the HGSSci subject is considered fundamental because, on the one hand, it structures the content, activities, and resources for the development of learning (Sáez-Rosenkranz, 2016) and, on the other hand, it has a responsibility in the construction of historical narratives, as it has an intrinsic stance in the discourses and narrative structure given to the teaching of history (Borres-Johnsen & Pomares, 1996; Pingel, 2010).

Reading levels

Statistical graphs require individuals to master specific knowledge and skills to understand the information. In this sense, Curcio et al. (Curcio, 1989; Friel et al., 2001; Shaughnessy et al., 1996) describe reading levels for statistical graph reading skills, which are defined below.

1. *Reading the data*. Taking the information from the graph without interpretations or calculations.
2. *Reading between data*. Comparing or performing arithmetic operations with the data, i.e., getting information using calculations or operations based on the graph representation.
3. *Reading beyond the data*. Making predictions and inferences based on data extracted from the graph, i.e., obtaining information that is not directly reflected in the statistical graph.
4. *Reading behind the data*. Critically evaluating the data, i.e., its data collection method, validity and reliability, and conclusions obtained.

Levels of semiotic complexity

Statistical graphs are made up of various elements, such as a complex semiotic object where each type of representation has its own construction and interpretation conventions. Arteaga (2011) and Batanero et al. (2010) describe the following levels of semiotic complexity for statistical graphs.

1. *Individual data representation*. A graph with isolated data, not representing the data set altogether. These graphs do not use concepts of variable and distribution.
2. *Representing a data list without forming a distribution*. A graph where all the data in a set are presented, one by one, without grouping similar data or calculating associated frequencies. For this level, the idea of variable is already used, but not the idea of distribution.
3. *Representing data distribution*. A graph where data distribution is grouped per characteristic, obtaining the frequencies corresponding to each category. At this level, objects of numerical order, variables, frequencies, and distribution are considered.
4. *Representing several distributions on the same graph*. Representing more than one frequency distribution in the same statistical graph.

BACKGROUND

This work is based on other investigations that analyse the statistical graphs present in textbooks. These are essentially developed in mathematics. Then, the investigations carried out in NSci and HGSSci are addressed.

In mathematics, statistical graphs studies are varied and cover different aspects of this element of statistical culture. For example, Diaz-Levicoy, Batanero, et al. (2016) conducted a comparative study of statistical graphs in elementary education textbooks in Chile and Spain. They analysed 18 textbooks, the types of tasks proposed, the graphs involved, the required reading level, and the semiotic complexity. The results showed that the books conform to the curricular guidelines regarding which graph to work on, showing a difference in the number of activities between the Chilean (508) and Spanish (215) textbooks. Regarding the types of tasks, the Spanish and Chilean texts mostly ask for reading and calculating, respectively. In addition, in the textbooks in both countries, the graph bar, reading level 2 (reading between the data), and semiotic complexity level 3 (representing data distribution) stand out. The bar graph is the most commonly used data representation in textbooks from both countries, mainly featuring reading level 2 (reading between the data) and semiotic complexity level 3 (representing data distribution).

Bustamante-Valdés and Díaz-Levicoy (2020) analysed the activities that involved statistical graphics in the modules proposed by the Chilean Ministry of Education for multigrade field education. The results show the predominance of the bar graph, reading level 2 (reading between the data), semiotic complexity 3 (representing distribution), calculating, and personal context.

In NSci, Jesús et al. (2013) conducted a study on statistical graphs to analyse 12 physical-chemical science textbooks from the third cycle of elementary education [7th, 8th, and 9th grades] in Portugal. The results showed the preponderance of bar and circular graphs. They also showed deficiencies in the graphs at the title level, the specifications, and the minimum requirements for Curcio's (1989) reading levels 2 and 3 for reading and interpretation.

Diaz-Levicoy, Pino, et al. (2016) analysed the activities related to statistical graphs present in 12 NSci textbooks for elementary education in Chile. The results evidenced the predominance of bar and line graphs, the reading-the-data level, the semiotic complexity of the representation of data distribution, and the explaining and comparing tasks. Subsequently, Díaz-Levicoy et al. (2017) studied the potential semiotic conflicts in statistical graphs in these 12 textbooks. The results showed the following potential semiotic conflicts on statistical graphs: absence of titles and labels, errors in the scales, and the use of the third dimension without meaning.

In the HGSSci area, Díaz-Levicoy and Sánchez (2016) studied the statistical graphs in 7th and 8th-grade textbooks of elementary education in Chile. The findings revealed a strong prevalence of thematic maps, while graphs were both limited in number and lacking in variety.

Sáez-Rosenkranz (2016) analysed activities in the 5th and 6th-grade textbooks of the HGSSci of Chilean elementary education used in 2014. In this study, among the variables examined, we identified activities related to statistical graphs, which show that this resource is one of the most used in the 5th grade for learning. Likewise, thematic maps are one of the most used visual resources in both grades.

Finally, Gómez and López-Martínez (2014) analyse the images of the textbooks of three publishers of the subject of Social Sciences, Geography, and History in the 4th grade of the regular compulsory secondary education (12-16 years old) in Spain. They analysed the image as a didactic resource for developing historical knowledge. Among the results, the importance of statistical graphs and thematic maps in their informative function stands out in relation to the text.

METHODOLOGY

This research follows a qualitative methodology (Pérez-Serrano, 1994). The method used is content analysis (López-Noguero, 2002). The sample of 24 textbooks is intentional (Hernández et al., 2010) and selected because they are used from the 1st to the 6th grade of elementary education. In each subject, we considered two series of textbooks (two at each level from each publisher), written and edited following curriculum guidelines (MINEDUC, 2018). The first series of textbooks correspond to those published by MINEDUC, which are delivered free of charge to students in each educational establishment, whether municipal or subsidised private. The second series of textbooks are those by the SAVIA project of SM, distributed in the internal market[1]. We used codes according to the publisher, subject, and grade to facilitate their identification and reading. Table 1 presents the list of textbooks analysed.

Table 1

List of textbooks analysed per subject.

Code	Authors (Year)	Title	Publishing house
TH1	Cabreras & Bugueño (2020)	Historia, Geografía y Ciencias Sociales 1º básico [History, Geography, and Social Sciences 1st basic]	MINEDUC
TH2	Quiñones, Poblete, & Muñoz (2019)	Historia, Geografía y Ciencias Sociales 2º básico [History, Geography, and Social Sciences 2nd basic]	MINEDUC
TH3	Latorre, Palacios, & Rodríguez (2019)	Historia, Geografía y Ciencias Sociales 3º básico [History, Geography, and Social Sciences 3rd basic]	MINEDUC

[1]This research was not evaluated by a Scientific Ethics Committee, since it was not carried out with human beings. Still, the journal Acta Scientiae is exempted from any liability derived from the collection and analysis of data described in the article, according to Resolution N. 510, of April 7, 2016, of the Ministry of Health of Brazil.

Code	Authors (Year)	Title	Publishing house
TH4	Fernandez, Fuentes, & Panza (2019)	Historia, Geografía y Ciencias Sociales 4º básico [History, Geography, and Social Sciences 4th basic]	MINEDUC
TH5	Flores (2020)	Historia, Geografía y Ciencias Sociales 5º básico [History, Geography, and Social Sciences 5th basic]	MINEDUC
TH6	Garrido & Olate (2019)	Historia, Geografía y Ciencias Sociales 6º básico [History, Geography, and Social Sciences 6th basic]	MINEDUC
TH7	Giadrosic (2016)	Historia, Geografía y Ciencias Sociales 1º básico [History, Geography, and Social Sciences 1st basic]	SM
TH8	Giadrosic & Tobar (2016)	Historia, Geografía y Ciencias Sociales 2º básico [History, Geography, and Social Sciences 2nd basic]	SM
TH9	Quiroz & Henríquez (2016)	Historia, Geografía y Ciencias Sociales 3º básico [History, Geography, and Social Sciences 3rd basic]	SM
TH10	Sepúlveda, Henríquez, & Hausdorf (2016)	Historia, Geografía y Ciencias Sociales 4º básico [History, Geography, and Social Sciences 4th basic]	SM
TH11	Henríquez, Torrejón, & Editorial Team (2016)	Historia, Geografía y Ciencias Sociales 5º básico [History, Geography, and Social Sciences 5th basic]	SM
TH12	Avalos, Henríquez, Luque, & Olate (2016)	Historia, Geografía y Ciencias Sociales 6º básico [History, Geography, and Social Sciences 6th basic]	SM
TC1	Ortiz, Russi, & Vera (2020)	Ciencias Naturales 1º básico [Natural Sciences 1st basic]	MINEDUC
TC2	Ortiz & Russi (2020)	Ciencias Naturales 2º básico [Natural Sciences 2nd basic]	MINEDUC
TC3	Calderon & Gutierrez (2019)	Ciencias Naturales 3º básico [Natural Sciences 3rd basic]	MINEDUC
TC4	Molina, Morales & Ortiz (2019	Ciencias Naturales 4º básico [Natural Sciences 4th basic]	MINEDUC
TC5	Rojas & Valdes, (2019)	Ciencias Naturales 5º básico [Natural Sciences 5th basic]	MINEDUC
TC6	Morales, Ortiz, & Valdebenito (2019)	Ciencias Naturales 6º básico [Natural Sciences 6th basic]	MINEDUC
TC7	SM Pedagogical Team (2016)	Ciencias Naturales 1º básico [Natural Sciences 1st basic]	SM
TC8	Águila & SM Pedagogical Team (2016)	Ciencias Naturales 2º básico [Natural Sciences 2nd basic]	SM

Code	Authors (Year)	Title	Publishing house
TC9	Águila & Molina (2016)	Ciencias Naturales 3º básico [Natural Sciences 3rd basic]	SM
TC10	Águila, Atala & Molina (2016)	Ciencias Naturales 4º básico [Natural Sciences 4th basic]	SM
TC11	Águila & Molina (2016)	Ciencias Naturales 5º básico [Natural Sciences 5th basic]	SM
TC12	Águila & Atala (2016)	Ciencias Naturales 6º básico [Natural Sciences 6th basic]	SM

In these textbooks, we identified activities that involve working with statistical graphics, considering for this study the following units of analysis:

1. *Graph type*. Those considered in the curriculum guidelines of MINEDUC (2018) and those mentioned in previous research (Arteaga, 2011; Bustamante-Valdés & Díaz-Levicoy, 2020; Díaz-Levicoy, Batanero et al., 2016).
2. *Reading levels*. Those described by Curcio et al. (Curcio, 1989; Friel et al., 2001; Shaughnessy et al., 1996), who propose the following levels: (1) Reading the data; (2) Reading between the data; (3) Reading beyond the data, and (4) Reading behind the data.
3. *Levels of semiotic complexity*. Those described by Arteaga (2011) and Batanero et al. (2010): (1) Representation of individual data; (2) Representation of a data set without forming a distribution; (3) Representation of a data distribution, and (4) Representation of several distributions on the same graph.
4. *Task types*. Those described in previous research are considered and adapted (Bustamante-Valdés & Díaz-Levicoy, 2020; Castellanos, 2013; Díaz-Levicoy & Arteaga, 2014; Díaz-Levicoy, Batanero et al., 2016).

RESULTS

Distribution of activities

Table 2 shows the distribution of activities that involve statistical graphs in NSci textbooks by both publishers, the MINEDUC and the SM. Generally speaking, the results show that the activities are mainly concentrated in the 5th (29.4%) and the 6th (47%) grades. If analysed per publisher, the 6th grade concentrates the most activities (MINEDUC 50% and SM 44.4%). These results coincide with those presented in Díaz-Levicoy, Pino, et al. (2016) and Pino et al. (2014), where activities using statistical graphics are incorporated from 2nd grade onwards, mainly with pictograms. However, this distribution of activities under the curriculum guidelines should begin in the 3rd grade.

Table 2

Percentages of activities that involve statistical graphs in NSci textbooks.

Education level	MINEDUC (n = 32)	SM (n=36)	Total (n=68)
2nd	3.1	2.7	2.9
3rd	9.3	11.1	10.2
4th	9.3	11.1	10.2
5th	28.1	30.5	29.4
6th	50.0	44.4	47

Table 3 shows the distribution of the activities in the HGSSci textbooks, in which the activities with statistical graphs are found exclusively in the 5th (21%) and 6th (78.3%) grades for both publishers, with a higher percentage of activities in the last year (MINEDUC, 80%; SM, 77.7%). Additionally, a considerable difference is evident between the publishers' activities, since SM (27) has the highest number of activities compared to MINEDUC (10).

Table 3

Percentages of activities that involve statistical graphs in HGSSci textbooks.

Education level	MINEDUC (n=10)	SM (n = 27)	Total (n=37)
5th	20	22.2	21.6
6th	80	77.7	78.3

On the one hand, these results coincide with the analysis of the activities related to statistical graphs in the curriculum guidelines for the HGSSci teaching from the 1st to the 8th grade of elementary education (Pino et al., 2014), where the absence of activities related to statistical graphs in the early school years (1st to 4th grade) is noticeable. Our results also show that the initiatives outlined in the curricular bases, where skills in analysis and work with information sources such as tables and statistical graphs are promoted from the 3rd grade onwards, are not considered. Similarly, they differ from those obtained by Sáez-Rosenkranz (2016) in a study with the 5th and 6th-grade books of HGSSci of elementary education in Chile, where most of the activities related to statistical graphs are concentrated in the 5th grade, considering over 70% of the activities between both levels.

The previous results show important differences in the number of activities per subject, since NSci concentrates 68 of them, while HGSSci only 37. To a large extent, this situation is due to the absence of activities with statistical graphs in the lower grades for HGSSci. For the HGSSci and the NSCi, the activities are concentrated in the upper courses (5th and 6th).

Graph types

The most frequent statistical graphs in the activities analysed in NSci textbooks, according to Table 6, are bars (36.7%), sectors (25%), and lines (22%). We observe that the pictograms (8.8%) are presented mainly in the first years, while the bar graphs are from the 3rd grade. These results show a predominance of bar graphs, consistent with other research in mathematics textbooks (Bustamante-Valdés & Díaz-Levicoy, 2020; Díaz-Levicoy, Batanero et al., 2016), which differ from the results obtained by Jesús et al. (2013) in their research in secondary education NSci textbooks, where the most frequent graph is the circular one.

The results of the 5th and 6th-grade textbooks of the SM publishing house coincide with the study by Díaz-Levicoy, Pino et al. (2016) in terms of the guidelines of the mathematics curriculum framework and the greater variety of statistical graphs, but not in the MINEDUC textbooks. On the other hand, the results in the first years show graphs of sectors and lines even though, per the mathematics curriculum guidelines, they are explicit from the 5th and 6th grades.

Taking into account that most semiotic conflicts occur in the 5th and 6th grades (Díaz-Levicoy et al., 2017), it is crucial to ensure that the activities developed from graphs have been worked on in the mathematics subject, mainly to avoid difficulties in understanding concepts and phenomena typical of science (Díaz-Levicoy, Pino, et al., 2016).

Table 6

Percentages of the type of graph present in natural science textbooks.

Graph type	MINEDUC					SM					Total (n=68)
	2nd (n = 1)	3rd (n = 3)	4th (n = 3)	5th (n=9)	6th (n=16)	2nd (n = 1)	3rd (n = 4)	4th (n = 4)	5th (n=11)	6th (n=16)	
Bars		33.3	100	55.5	18.8		25	50	36.3	37.5	36.7
Lines				11.1	43.8			50	9.1	25	22
Sectors		33.3		33.3	37.5				27.2	25	25
Pictogram	100	33.3				100	75				8.8
BM									9.1	6.3	2.9
LM									9.1		1.4
NE									9.1	6.3	2.9

Note: BM: Multiple bars; LM: Multiple line; NE: Does not specify

Next, in Table 7, the results are presented in the types of graphs in the HGSSci textbooks for elementary education, observing the predominance of bar graphs (21.6%), sectors (16.2%), lines (13.5%), and climatograph and area (10.8%), coinciding with studies in mathematics (Bustamante-Valdés & Díaz-Levicoy, 2020; Díaz-Levicoy, Batanero et al., 2016). On the contrary, these results differ from what Díaz-Levicoy and Sánchez (2016) observed, where the most frequent graphic in HGSSci textbooks is the cartogram.

Table 7

Graph-type percentages present in HGSSci textbooks

Graph type	MINEDUC		SM		Total (n=37)
	5th (n = 2)	6th (n=8)	5th (n = 6)	6th (n=21)	
Bars		25	33.3	19	21.6
Lines				23.8	13.5
Sectors	50	25	33.3	4.7	16.2
Climograph		12.5		14.2	10.8
Area			16.6	14.2	10.8
Multiple bars	50		16.6	4.7	8.1
Multiple lines		12.5		9.5	8.1
Cartogram		12.5			2.7
Stacked bars		12.5		9.5	8.1

In these results, several kinds of graphs stand out in both publishers for the 6th grade, introducing the work with climatographs, area graphs and cartograms or thematic maps. These findings differ from those obtained by Díaz-Levicoy and Sánchez (2016). In this sense, we must point out that cartograms or thematic maps are representations developed exclusively in this subject, a situation that should be considered in the mathematics study plans to improve the progression of the students' analysis and graphic representation skills in this type of graphs. Also, this type of representation is one of the most used resources in the teaching process in HGSSci textbooks for elementary education in Chile (Díaz-Levicoy & Sánchez, 2016; Sáez-Rosenkranz, 2016).

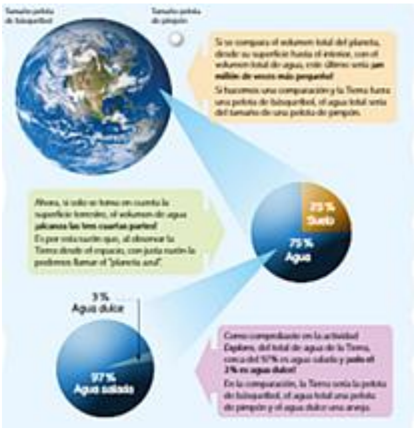
Based on the previous results, it is evident that in both subjects, bar, line, and sector graphs are mostly used: 83.7% for NSci and 51.3% for HGSSci of the total activities in textbooks, respectively. It is important to point out that in this last subject, there is a balanced number of activities involving different graphs.

Reading levels

Thirdly, we analyse the reading levels of the statistical graphs in the activities of the textbooks of both subjects and publishers, respectively. For this, we have used the levels described by Curcio et al. (Curcio, 1989; Friel et al., 2001; Shaughnessy et al., 1996)

Figure 1

Reading level 1 example (extracted from TC11, 2016, p.141)

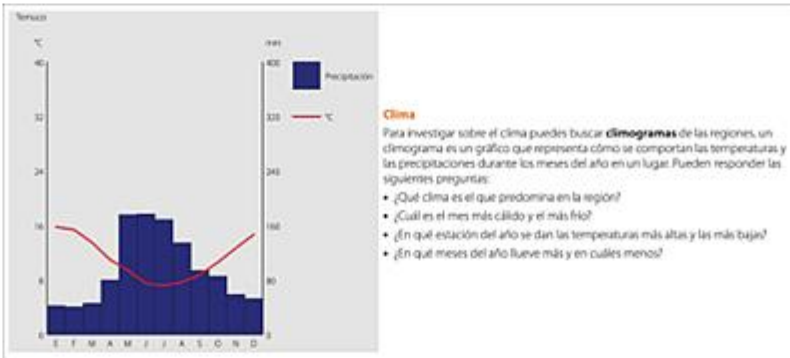


An example of the first level of "reading the data" is shown in Figure 1, where a graph in which the student must observe the percentage of soil and water on the planet is presented. In this case, the student must perform a literal reading of the data in the circular graph corresponding to 25% soil and 75% water, of which 97% is salt water and 3% fresh water.

Level 2, "reading between the data", is exemplified in Figure 2, which shows the rainfall in Temuco over a year. In this activity, students must make comparisons to determine the predominant value or find maximum and minimum values concerning temperatures and rainfalls.

Figure 2

Reading level 2 example (adapted/extracted from TH6, 2019, p.190)



Level 3, "reading beyond the data", is represented in Figure 3, where electricity consumption in Chile is shown from 2007 to 2017. For question d) How should the amount of energy consumed in 2020 compare to previous years? The student must predict the electrical consumption based on what is represented to answer a question asking for information not explicitly found in the bar graph.

Figure 4 shows the "reading behind the data" level, representing the intensity levels of different sounds. To answer the question, "What sounds could cause damage to the ears when exposed to them for a long time?" the student must issue an opinion. This process requires reflection and understanding of the information displayed in the graph, the context in which the data is given, and the measurement parameters used.

Figure 3

Reading level 3 example (Extracted from TC6, 2019, p.196)

Figure 4

Reading level 4 example (adapted/extracted from TC3, 2019, p.100)

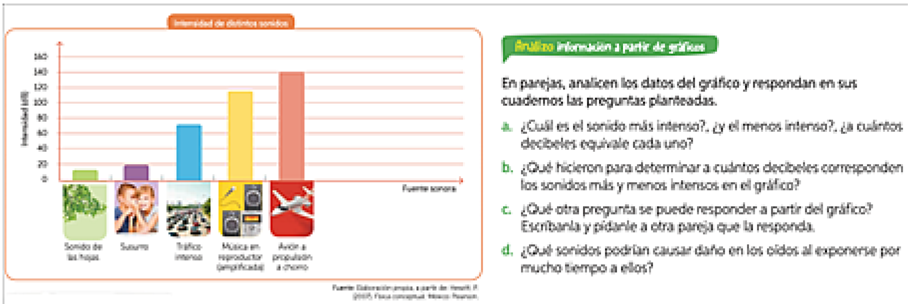


Table 8 shows the results of the reading levels of the statistical graphs in the NSci books. We can observe the predominance of the levels read behind the data (69.1%) and read the data (16.2%). These results differ from the previous analysis by Díaz-Levicoy, Pino et al. (2016), where a more significant presence of reading levels 1, 2 and 4 is evident, and with Jesús et al. (2013), where most of the activities were at reading level 1.

On the other hand, these results show a lack of progression between reading levels, a situation mentioned in various investigations on mathematics textbooks for elementary education in Chile (Bustamante-Valdés & Díaz-Levicoy, 2020; Díaz-Levicoy, Batanero et al., 2016). Our results also coincide with previous studies, which indicate the scarce presence of activities that require level-3 reading throughout the entire elementary education.

Table 8

Percentages of the reading levels required in the activities in the NSci textbooks.

Reading level	MINEDUC 2nd (n = 1)	3rd (n = 3)	4th (n = 3)	5th (n=9)	6th (n=16)	SM 2nd (n = 1)	3rd (n = 4)	4th (n = 4)	5th (n=11)	6th (n=16)	Total (n=68)
1				11.1	25				9.1	31.3	16.2
2	100			33.3	6.3					6.3	8.8
3				11.1	6.3					6.3	4.4
4		100	100	44.4	62.5	100	100	100	90.9	56.3	69.1

For this reason, prediction skills (level 3) seem to be hardly worked on in Mathematics (Díaz-Levicoy, Batanero et al., 2016). However, NSci (Díaz-Levicoy, Pino, et al., 2016; Jesús et al., 2013) works with many activities. Therefore, it is necessary to establish coherent guidelines between both subjects to favour a harmonic progression in the reading levels required in activities that involve statistical graphs to develop the various reading skills optimally and appropriately for each course and subject.

According to Table 9, in the HGSSci textbooks, the reading levels required in the activities are concentrated to a greater extent in reading the data (43.2%), followed by reading between the data and reading behind the data, both with 27%. If analysed per publisher, the results show, in the case of MINEDUC, the level of reading behind the data (60%) and reading between the data (40%) predominates, and, in SM, the levels of reading the data (59.3%) and reading between the data (22.2%).

Table 9

Percentages of the reading levels required in the activities in the NSci textbooks.

Reading level	MINEDUC 5th (n = 2)	6th (n=8)	SM 5th (n = 6)	6th (n=21)	Total (n=37)
1			50	61.9	43.2
2	50	37.5	50	14.2	27
3				4.7	2.7
4	50	62.5		19	27

Concerning the previous paragraph, the reading levels required in the activities follow the trend of other investigations where the results show a predominance of the levels of reading the data and reading within the data (Bustamante-Valdés & Díaz-Levicoy, 2020; Díaz-Levicoy, Batanero et al., 2016), although many reading level 4 activities are evident.

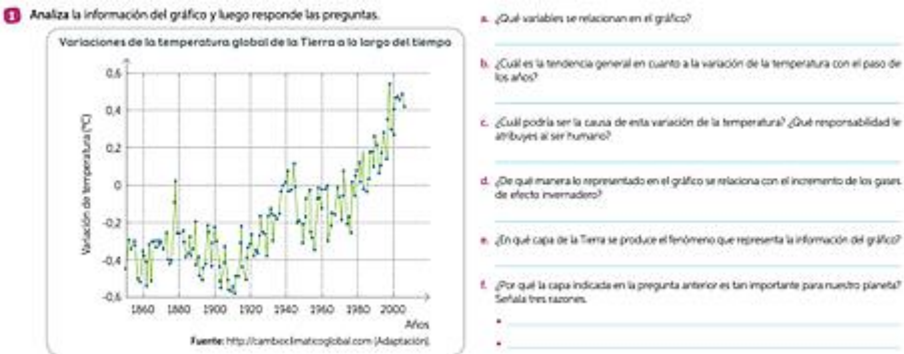
The reading levels in both subjects, in general, show differences in their results, mainly in the predominance that evidenced the reading level in HGSSci, compared with NSci, which is mostly reading behind the data. On the other hand, the reading level with the least presence in the activities for both subjects is reading beyond the data, which is intended for students to make predictions and inferences based on the data represented. This skill is one of the least adressed and with the least presence in elementary school textbooks both in mathematics and science and history.

Levels of semiotic complexity

The following unit of analysis corresponds to the levels of semiotic complexity described by Batanero et al. (2010) and Arteaga (2011), which are exemplified below:

Figure 5

Example level 2 of semiotic complexity (adapted from TC6, 2019, p.220)



The level 2 representation of a data set is exemplified in Figure 5, which brings the variations of the Earth's global temperature over time. The graph represents the temperatures of the planet in different stages but without grouping similar values, so the idea of a variable is handled, but the idea of frequency distribution is not.

The level of semiotic complexity representing a data distribution is shown in Figure 6, representing the percentage frequencies of erosion of the total soil surface in Chile, including light, moderate, and severe erosion. In this graph, each category has a frequency related to a total and does not represent isolated data.

Figure 6

Example level 3 of semiotic complexity (extracted from TH11, 2016, p.127)

Regarding level 4 of semiotic complexity (Representation of various distributions), an example is the graph shown in Figure 7, which details the percentage of obesity in Chilean men and women according to their age range in 2014. Here, the information presents two distributions according to the sex of the individual, one for men and another for women, according to the age range of each.

At the levels of semiotic complexity described above, we observe that level 1 (representation of individual data) is not present in the textbooks analysed.

Table 10 details the results that refer to the levels of complexity in the statistical graphs in the NSci books. It indicates that the levels of representation of data distribution (57.3%) and representation of a data set (39.7%) are the most frequent. Furthermore, a scarce presence of the level representation of various distributions is observed (2.94%). These results show a concentration of 97% between levels 2 and 3 of semiotic complexity. The predominance of level 3 in the graphs presented coincides with the results obtained by Bustamante-Valdés and Díaz-Levicoy (2020) and Díaz-Levicoy, Batanero et al. (2016) in mathematics textbooks. Moreover, they differ from the results of the research by Díaz-Levicoy, Pino et al. (2016), where level 2 appeared more in NSci textbooks.

Figure 7

Example level 4 of semiotic complexity (extracted from TC12, 2016, p.83)

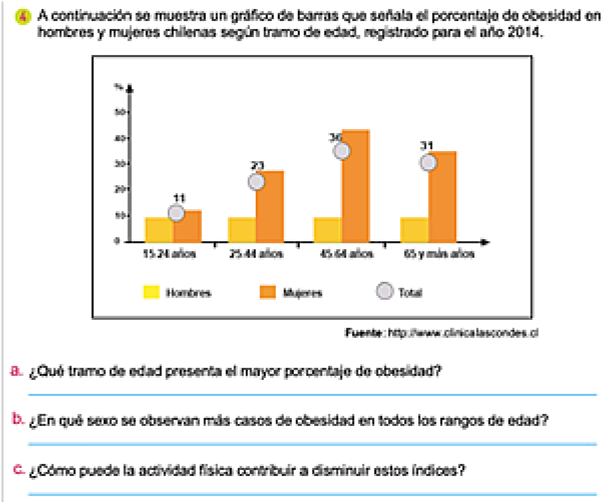


Table 10

Percentages of semiotic complexity levels in statistical graphs in NSci textbooks.

Semiotic level	MINEDUC 2nd (n = 1)	MINEDUC 3rd (n = 3)	MINEDUC 4th (n = 3)	MINEDUC 5th (n=9)	MINEDUC 6th (n=16)	SM 2nd (n = 1)	SM 3rd (n = 4)	SM 4th (n = 4)	SM 5th (n=11)	SM 6th (n=16)	Total (n=68)
2		33.3	33.3	44.4	56.3			75	27.2	37.5	39.7
3	100	66.6	66.6	55.5	43.8	100	100	25	63.6	56.3	57.3
4									9.1	6.3	2.9

Table 11 shows the distribution of the levels of semiotic complexity of the statistical graphs in the HGSSci textbooks. It shows a greater presence of the levels of representation of a data set of (48.6%) and representation of data distribution (40.5%). These results show a concentration close to 90% between levels 2 and 3 of semiotic complexity, coinciding with those reported in Jesús et al. (2013) in NSci textbooks and with Díaz-Levicoy, Batanero et al. (2016) in mathematics textbooks.

Table 11

Percentages of semiotic complexity levels in statistical graphs in NSci textbooks.

Semiotic level	MINEDUC		SM		Total (n=37)
	5th (n = 2)	6th (n=8)	5th (n = 6)	6th (n=21)	
2	0	25	16.6	71.42	48.6
3	50	50	66.6	28.5	40.5
4	50	25	16.6	0	10.8

Based on the results obtained in the levels of semiotic complexity for the graphs presented in the NSci subject, a predominance of level 3 is evident, while in HGSSci, it is level 2. Another aspect to consider is the insufficient presence of level 4 in both subjects, possibly due to the greater demand for the analysis of the represented data.

Types of tasks

Fifthly, we describe the outcomes regarding the type of task required of students concerning statistical graphs in the NSci and HGSSci primary education textbooks in Chile.

Reading. It corresponds to a literal reading of the data presented in the graph, whether it is a frequency, a category, the title or the labels. Figure 5 exemplifies it by the question a) What variables are related in the graph? Then, the student must identify the information present in the labels of each axis of the line graph to respond.

Calculating. It is related to the execution of simple arithmetic operations with the information presented in the statistical graph.

An example of this task is presented in Figure 4, where the questions of activity a) "What is the most intense sound? And the least intense?" are answered using simple addition or subtraction algorithms.

Building. It involves the preparation of a statistical graph according to the information provided, whether listed or organised in a table or graph or must be collected. From this task, the student must know the elements of the graph: title, labels, frame (axes, scales and reference marks for each axis), specifiers, and background. An example of this task is found in Figure 8, where the student is asked to construct a bar graph with the data present in the table titled "Boiling points of different liquids".

Comparing. A task where the suitability of the type of graph to represent the data delivered is established. This task is exemplified in Figure 9, where the student must answer a question: Which graph best represents the amount of water on the Earth's surface? This is part of the final evaluation section of the unit. To answer this situation, the student must compare the pie charts and identify the appropriate one for the data they must know in advance.

Figure 8

Example of building task (extracted from TC6, 2019, p.127)

En una hoja cuadriculada construye un gráfico de barras que represente el punto de ebullición de distintos líquidos. Considera los pasos descritos en esta actividad.

Punto de ebullición de distintos líquidos

Sustancia	Punto de ebullición (°C)
Agua	100
Etanol	78
Benceno	80
Mercurio	357

Fuente: Chang, R., & Goldsby, K. (2013). *Química*. (11.ª Ed). McGraw-Hill: Ciudad de México. (Adaptación).

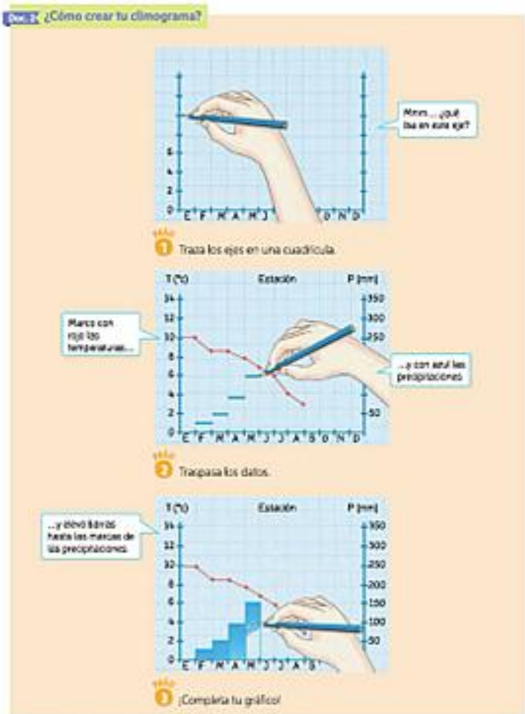
- ¿Qué título le pondrías al gráfico?

Figure 9

Example of comparing (extracted from TC11, 2016, p.170)

Figure 10

Example activity (extracted from TH12, 2016, p.141)

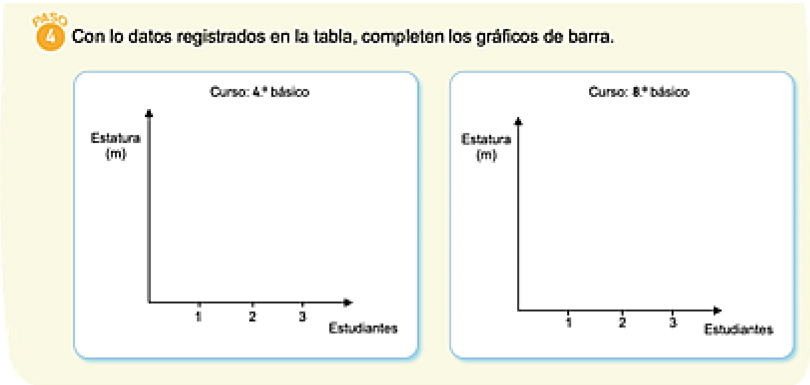


Exemplifying. It corresponds to a textbook section used to explain a concept, a form of construction, or how to interpret it. The graph can be used to clarify new ideas and/or presented concepts. An example of this is the graph in Figure 10, which details how a climogram is constructed or created step by step.

Completing. A task that requires completing the construction of a statistical graph according to the data and information provided, either by naming the title of the graph, the labels, or creating the specifiers, among others. Figure 11 shows an example of this task, which requires the assessed to complete the construction of a graph by creating the specifiers, which, in this case, are bars based on the data collected and organised in a table.

Figure 11

Example of completing (extracted from TC12, 2016, p.57)



Inventing. It consists of posing a new situation (question or problem) based on the data and information provided in a statistical graph. An example of this activity is found in Figure 4, specifically in the question c) "What other question can be answered from the graph?" In this activity, the student must create a question related to the intensities of some sounds using the data and information provided in the graph.

Explaining. It refers to the argumentation and justification provided by the student based on the procedures applied, conclusions obtained from the analysis of the graph and the points of view adopted. Figure 7, question c) exemplifies this task, because the student must argue that physical activity contributes to reducing obesity in people.

The results presented in Table 12 show the tasks required by each activity related to statistical graphics. The evidence, in general, in NSci shows that the most predominant task is explaining (33.3%), calculating (21.6%), and completing (14.1%). The results coincide with the study by Díaz-Levicoy, Pino et al. (2016). Likewise, it is important to note that research done with mathematics textbooks (Bustamante-Valdés & Díaz-Levicoy, 2020; Díaz-Levicoy, Batanero et al., 2016) considers the task of calculation to be among the most frequent, agreeing with the results of the present investigation.

Table 12

Percentages according to type of task required in statistical graphs in Natural Sciences textbooks.

	MINEDUC					SM					
Task	**2nd (n = 1)**	**3rd (n = 3)**	**4th (n = 3)**	**5th (n=9)**	**6th (n=16)**	**2nd (n = 1)**	**3rd (n = 4)**	**4th (n = 4)**	**5th (n=11)**	**6th (n=16)**	**Total (n=68)**
Reading					14.8			10	23.8	16	11.6
Calculating	50	50	14.2	10	22.2	100	36.3	20	14.2	16	21.6
Building			28.5		7.4		18.1		9.5	4	7.5
Comparing				10	3.7			20		4	4.1
Exemplifying	50			10	7.4				9.5	8	6.6
Completing			28.5	20	11.1		9.09	10	14.2	20	14.1
Inventing		16.6									0.8
Explaining		33.3	28.5	50	33.3		36.3	40	28.5	32	33.3

Table 13 shows the results of the type of task required for each activity related to statistical graphs in 5th and 6th grade for the HGSSci subject. In general terms, it is evident that the predominant tasks are example (37.7%), reading (20.7%) and explaining (16.9%). These results differ from other studies focusing on mathematics textbooks (Bustamante-Valdés & Díaz-Levicoy, 2020; Díaz-Levicoy, Batanero et al., 2016), where they consider the calculation task as the most frequent. Among the possible reasons why the example task is considered the most relevant in the HGSSci subject are the work with graphics that are unprecedented for the area of mathematics (climate charts, area charts, and cartograms) and the requirement denoted by the textbooks for supporting student learning in the analysis, interpretation, and construction of statistical graphs.

Table 13

Percentages according to type of task required in statistical graphs in Natural Sciences textbooks.

Type of task	MINEDUC 5th (n = 2)	MINEDUC 6th (n=8)	SM 5th (n = 6)	SM 6th (n=21)	Total (n=37)
Reading	50	10	16.6	22.8	20.7
Calculating	50			14.2	11.3
Building				8.5	5.66
Comparing		20	16.6		5.66
Exemplifying		40	33.3	40	37.7
Inventing				2.85	1.8
Explaining		30	33.3	11.4	16.9

The tasks required for the activities related to statistical graphs show mixed overall results. On the one hand, the predominance of the explaining task (33.3%) in NSci is evident, given the need to demonstrate and represent the phenomena or processes of science. On the other hand, the exemplifying task (37.7%) in the HGSSci subject is mainly used in teaching the construction of a type of graph. We believe this is because some representations are more difficult to prepare, as is the case of climograms and cartograms addressed only in this subject. These results differ from research about mathematics textbooks that show the calculation task as the predominant one in activities with statistical graphs.

CONCLUSIONS

To address the conclusions of this work, we will begin with the NSci textbooks, later with HGSSci, and end with some general conclusions that contrast both subjects, considering the two publishers.

First, the results for NSci textbooks demonstrate that the number of activities related to statistical graphs does not present significant differences, coinciding with the study by Díaz-Levicoy, Pino et al. (2016). The activities analysed showed that the most frequent graph is the bar graph, coinciding with previous research on mathematics textbooks (Bustamante-Valdés & Díaz-Levicoy, 2020; Díaz-Levicoy, Batanero et al., 2016) and differing from Jesús et al. (2013) on high-school NSci textbooks. Nevertheless, the 5th and 6th-grade textbooks from the SM publishing house coincide with the study by Díaz-Levicoy, Batanero et al. (2016) in terms of promoting a greater variety of graphics in textbooks, which agrees with the guidelines of the mathematics curricular framework for these levels. This situation is not reflected in textbooks designed for the MINEDUC. We should also mention that in the first courses, the presence of pie charts and lines is evident even though their work is made explicit in the mathematics curriculum from the 5th and 6th grades of primary school. Activities in NSci focus mainly on reading level 4 and semiotic complexity level 3. Explaining was the most required task in the activities involving statistical graphs.

Second, the HGSSci textbooks show a notable difference in the number of activities aimed at working with statistical graphs, depending on the publisher chosen. This is because the SM publishing house concentrates more than twice as many activities as the textbooks designed for the MINEDUC. Another relevant aspect is that most activities are concentrated mainly in the 5th and 6th grades. In this sense, we must highlight the importance of incorporating more activities of this type in the lower grades, even more so if the curricular guidelines promote the development of analysis skills and work with sources of information such as tables and statistical graphs from the first years of schooling. In the activities presented, the bar graph mainly predominates, contrasting with the results obtained by Díaz-Levicoy and Sánchez (2016), in which the cartogram found more activities in the 7th and 8th-grade textbooks in primary education in Chile. Therefore, it is fundamental to point out that cartograms or thematic maps are representations developed exclusively in this subject, a situation that should be considered in the mathematics study plans to improve the progression of students' analytical and graphic representation skills in this type of graphs. The above situation happens because this type of representation is one of the most used resources in the teaching process in HGSSci textbooks for primary education in Chile (Díaz-Levicoy and Sánchez, 2016; Sáez-Rosenkranz, 2016), and they fulfil a relevant, informative function since they provide an idea of the contexts represented in the textbooks (Gómez & López-Martínez, 2014).

Regarding the reading level, there is a predominance of reading the data (1), the level of semiotic complexity 2, and the most required task was exemplifying. Regarding the task above, this situation may be because the work with some graphic types - in certain aspects - are unprecedented since they are not explicitly addressed in mathematics, such as climograms, area graphs, and cartograms. Faced with this situation, textbooks denote the need to support student learning in terms of the analysis, interpretation, and construction of this type of statistical graphs.

Finally, both subjects present a considerable difference in the number of activities related to statistical graphs since the NSci exceeds HGSSci by approximately double. The low number of activities related to statistical graphs in this last subject was reflected in previous studies such as Pino et al. (2014), which shows the limited presence of activities using statistical graphs in the syllabuses for grades 1 to 8, as pointed out by Díaz-Levicoy and Sánchez (2016) in a study on textbooks for grades 7 and 8 of primary school. Regarding the most frequent type of graph, the activities in the textbooks show that the bar graph predominates in both the NSci and HGSSci areas. In the reading levels, both subjects differ, since in the area of NSci, the predominance of level 4 is evident, while in HGSSci, the level of reading the data predominates (1). Some relevant general aspects to consider are the predominance (80%) of levels 2 and 3 of semiotic complexity in all the activities presented for both subjects in the textbooks and the scarce presence of level 3 reading. This situation agrees with other studies in mathematics (Bustamante-Valdés & Díaz-Levicoy, 2020; Díaz-Levicoy, Batanero et al., 2016). Finally, the analysed activities show a greater frequency of the explaining task in NSci, coinciding with another research (Díaz-Levicoy, Pino et al., 2016). This situation could be due to the inherent scientific need to demonstrate and represent the phenomena specific to this area of knowledge. Furthermore, for the HGSSci subject, the most frequent task was exemplifying, whose main use is to teach the construction of specific graphs such as climograms or cartograms. This is due to the difficulty involved in building, analysing, and interpreting them, considering that this may be because this type of representation is not explicitly addressed in the mathematics subject.

AUTHORSHIP CONTRIBUTION STATEMENT

MBV conceived the idea of this research. MBV collected the data. The three authors (MBV, JPC, and DDL) actively participated in the development of the theory, methodology, organisation, and analysis of the data, discussion of results, and approval of the final version of the work.

DATA AVAILABILITY STATEMENT

The data supporting the results of this study will be made available by the corresponding author, MBV, upon reasonably previous request.

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