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Understanding statistical graphs of students attending multigrade rural schools in Chile

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ABSTRACT
This study aims to analyze the graphical comprehension of 5th and 6th grade students in multigrade rural primary education in Chile. The theoretical framework considers levels of reading and semiotic levels in statistical graphs. A qualitative methodology of descriptive level is followed, using content analysis method for the responses given to a questionnaire by 22 students from five multigrade rural schools. The results show that, overall, students do not encounter difficulties in answering questions at level 1 reading (literal reading), but difficulties gradually increase as the reading level increases. Regarding semiotic levels, difficulties arise in constructing graphs using data distribution (semiotic level 3) and completing a graph with two data distributions (semiotic level 4).

Keywords: statistics, primary education, statistical graphs, rural school, multigrade classroom

INTRODUCTION

In recent decades, statistics has been incorporated into the mathematics curriculum guidelines of various countries starting from primary education (Alsina & Vásquez, 2016; Batanero, 2001; Cuevas & Ramírez, 2018; Zapata-Cardona, 2018). This is explained by its utility in different scientific, social, and humanistic areas (Molina-Portillo et al., 2019), as well as in decision-making in everyday life (Del Pino & Estrella, 2012; Samuel et al., 2019). In this sense, citizens access vast amounts of information through the media, which use statistical representations to display data (Del Pino & Estrella, 2012; Vásquez, 2021), especially with statistical graphs (Arteaga et al., 2018; Vásquez, 2021), which are widely used in visual analysis (Luo et al., 2019). Therefore, it is imperative to develop statistical literacy in people, that is, to promote skills for both interpreting and critically evaluating statistical information, as well as discussing and communicating opinions based on data (English & Watson, 2015; Gal, 2002). Additionally, due to the ongoing changes in statistical processes that citizens encounter, including statistical graphs, it becomes necessary to learn new forms of communication and visualization (Wild, 2017). This is crucial for acting as an informed and critical citizen in an information-based society (Del Pino & Estrella, 2012). Educational centers prove to be important elements in the development of statistical literacy (Callingham & Watson, 2017). In this regard, within these educational institutions are rural schools, where, due to a series of contextual factors, their students face greater difficulties in learning compared to those attending urban schools (Cano, 2020; Juárez & Rodríguez, 2016; Raczynski & Román, 2014). Among these factors, the most significant issue is the presence of multigrade classrooms (Bustos, 2014; Little, 2007), which is understood as the way students of different ages come together and work in the same classroom (Abós & Boix, 2017). It is also relevant to note that, to date, educational policies in most countries are oriented towards average urban schools, with little relevance and pertinence in curricular contents for rural schools (Cano, 2020; Raczynski & Román, 2014). This highlights a significant challenge, as this situation directly affects the students' learning development.

In Chile, the mathematics curriculum guidelines, both for rural and urban education, are divided into five thematic axes aimed at grade 1 to grade 6 of primary education, which are, as follows:

(a) numbers and operations,
(b) patterns and algebra,
(c) geometry,
(d) measurement, and
(e) data and probabilities.

The latter includes work with statistical graphs, aiming to help students develop:

> (...) initial ideas of how to collect information and how to organize data obtained from surveys or questions that children must learn to construct, and also use some counting and classification techniques of said data, to subsequently represent them in tables and/or graphs (MINEDUC, 2014, p. 3).

The graphs stated in the curriculum guidelines and their respective educational levels are pictograms (1st to 4th), bar graphs (2nd to 6th), dot plots (3rd and 6th), lines (5th), stem-and-leaf (5th and 6th), and sectors (6th).

Therefore, based on the aforementioned considerations, this research aims to analyze the understanding of statistical graphs among 5th and 6th grade primary education students attending rural schools with multigrade classrooms, as these represent the last grades of this type of schools and should have the knowledge established in the curriculum regarding statistical graphs.

THEORETICAL FOUNDATIONS

Key skills related to statistical graphs include reading and constructing such representations, which require a certain skill of knowledge and the ability to understand and represent statistical information. In this context, the levels of reading (Curcio, 1989; Friel et al., 2001; Shaughnessy et al., 1996) and levels of semiotic complexity (Arteaga, 2008, 2011; Batanero et al., 2010) are particularly noteworthy, and are described, as follows.

Levels of Reading

Reading statistical graphs is a complex activity, which has been studied by various researchers. In this regard, and considering that it is possible to pose questions of different levels of difficulty for the same graph, Curcio (1989), Friel et al. (2001), and Shaughnessy et al. (1996) describe levels related to reading a graph:

- **N1. Reading data:** reading data literally, identifying values and/or structural elements of the statistical graph. This level requires comprehension of specific aspects of the statistical graph.
- **N2. Reading between data:** in addition to literal reading, it requires performing simple mathematical calculations or comparisons of data shown in the statistical graph to obtain new information.
- **N3. Reading beyond data:** involves making predictions of values that are not present in the statistical graph, based on the information contained in it. That is, it involves interpolating or extrapolating the data.
- **N4. Reading behind data:** it requires a critical assessment of the data collection, presentation, and analysis processes, as well as the conclusions drawn.

Levels of Semiotic Complexity

On the other hand, Arteaga (2008, 2011) and Batanero et al. (2010) recognize the complexity of constructing statistical graphs due to the numerous semiotic elements involved, which must be understood both individually and collectively. These authors propose the following semiotic levels:

- **N1. Representation of isolated data:** isolated data points are presented in the statistical graph.
- **N2. Representation of a set of data without summarizing its distribution:** a list of data is presented one by one, without utilizing the idea of frequency or frequency distribution, but rather that of variables.
- **N3. Representation of a data distribution:** displays a data distribution in a statistical graph, calculating involved frequencies.
- **N4. Representation of multiple data distributions:** shows two or more data distributions in the same statistical graph.

Background

The literature reports the existence of various studies that have analyzed the reading and construction of statistical graphs in primary education students. These studies are summarized below.

Regarding levels of reading, Batanero et al. (2018) evaluated the reading level and translation ability of 745 6th and 7th grade students in Chilean primary education. They found that students demonstrated good comprehension of pictograms when translating them into statistical tables (75.4%), although they encountered difficulties in identifying the accuracy of statements related to the pictogram information (64.0%). Rodríguez (2019) studied the reading levels of 84 8th grade students when interpreting two types of graphs (bar graph and pie charts), where 52.4% managed to read data (level 1) and 31.0% performed mathematical calculations to obtain information (level 2). Díaz-Levicoy and Batanero (2020) assessed the competence of translating data presented in a double bar graph into a double-entry table in a sample of 380 6th-grade students in primary education. Their results highlighted a low success rate (38.0%), with the main errors being related to the construction of a tally table or marginal distribution, creating another graph, and other less significant errors. Hernández et al. (2021) evaluated the graphical comprehension of bar graphs and pictograms in 6th grade students in primary education in Mexico. Their results showed a predominance of level 2 reading, which they considered appropriate for the level when compared with Mexico's curriculum guidelines. Arteaga et al. (2021) studied the reading of line graphs by Chilean 6th and 7th grade primary education students. Their analysis revealed a 94.4% correct response rate in reading the title, 18.4% in describing the variables of the graph, 93.3% in reading data, and 62.6% in inverse reading of a data point and selecting the correct graph. However, only 13.7% of the students managed to give a correct response to questions demanding a level 4 reading.

On the other hand, concerning the construction of statistical graphs by primary education students, Díaz-Levicoy et al. (2018) analyzed the responses of 745 students in two tasks. In the first task, students had to construct bar graphs from a list of data (semiotic level 2), and in the second task, they had to create a frequency distribution (semiotic level 3). Their findings showed that 75.3% of students produced partially correct and correct constructions (6.0% and 69.3%, respectively) in the first task, while in the second task, the success rate did not reach 50.0%. The main errors were related to labeling, scale construction, variable range setting, bar width or spacing, omission of values, or representation of data without summarization. Guimarães et al. (2001) reported results of bar graph constructions by 107 Brazilian 3rd grade primary education students, demonstrating the absence and difficulties in creating scales. Evangelista et al. (2014) analyzed the performance of 46 5th grade Primary Education students in Brazil regarding the construction of two unspecified types of graphs. Their results showed that 88.1% of students managed to construct the two graphs, but without including titles, and only 3.3% added names to the axes. Ruiz (2015), in the Colombian context, analyzed the construction of statistical graphs by 31 5th grade primary education students, highlighting errors in selecting representations according to the nature of the data, difficulties in constructing scales, and the absence of labels facilitating understanding of the information present in the statistical graph. Finally, Cruz (2013) analyzed the constructions of 3rd grade primary education students in Portugal, revealing errors associated with the construction of bar graphs. Their results showed the absence of legends on the axes, bars with different widths and spacing between them, incorrect assignment of variable categories on the graph, failure to select a constant unit for scales, and failure to indicate them on the axes.

While there are studies in various countries and at different levels of primary education, there are no reports of studies analyzing the reading and construction of statistical graphs by primary education students attending multigrade rural schools.

METHODOLOGY

In accordance with the purpose of this study, a qualitative methodology (Creswell & Poth, 2018) of descriptive level (Mishra & Alok, 2017) is followed, utilizing content analysis as the method (Piñeiro-Naval, 2020) for the responses to a questionnaire administered to 22 Chilean students in 5th and 6th grades of multigrade rural primary education, from five schools in the Maule Region, including all students attending upper-level courses, which were selected by means of a non-probabilistic purposive sampling (McMillan & Schumacher, 2005). Rural schools were chosen because researchers could easily access them. In addition, it is worth mentioning that the common factors of these schools are that they belong to the same rural microcenter, given their proximity and their belonging to the same commune, where teachers share and agree on teaching strategies and methodologies to work with students of different ages in a common classroom. Other common characteristics of the participants in this study are their age range, socioeconomic level and scarce access to technological resources. The courses were chosen because they are part of the same multigrade classroom and are in the final stage of primary education, implying the students should be familiar with all graphical representations taught at this level. The advantage of this context is that fifth graders can work on sixth grade content, and the latter can reinforce learnings from previous years. This situation justifies the use of the same assessment tool for both groups. The instrument was applied only once in each establishment. Visiting hours were scheduled with the teachers in charge, so that in two days, the questionnaire could be applied in the five establishments. The questionnaire was also answered individually (**Appendix A**).

For the development of the questionnaire, a review of the curriculum guidelines and Chilean mathematics textbooks for multigrade rural education (Bustamante-Valdés & Díaz-Levicoy, 2020, 2024) was conducted. These textbooks were analyzed using the same variables that we employed in designing this instrument, which are detailed below:

(1) types of graphs mentioned in national curriculum guidelines (MINEDUC, 2014),

(2) level of reading (Curcio, 1989; Friel et al., 2001; Shaughnessy et al., 1996),

(3) level of semiotic complexity (Arteaga, 2011; Batanero et al., 2010),

(4) types of tasks described in research on textbooks (Bustamante-Valdés & Díaz-Levicoy, 2020; Díaz-Levicoy, Batanero et al., 2016; Díaz-Levicoy, Giacomone et al., 2016; Díaz-Levicoy et al., 2017; Díaz-Levicoy, Osorio et al., 2018; Jiménez-Castro et al., 2020), including: reading (literal reading of data or elements of the graph such as title, axes, scale, among others), calculating (simple arithmetic operations must be performed to obtain information, including data comparison), constructing (a graph must be created from data presented in tables or without their use), completing (finalizing the construction of a statistical graph by assigning missing data, titles, labels, constructing bars, among others), converting to table (transferring data from a graph to a statistical table), predicting (making estimations based on data present in the statistical graph), comparing graphs (comparing two or more graphs regarding, which is most suitable for representing certain data), creating a question (formulating questions to obtain information from data in a statistical graph), and justifying (reasoning from situations, explaining processes, or arguing from viewpoints), and

(5) contexts described in PISA test (Organization for Economic Co-operation and Development [OECD], 2023): personal (situations close to the student, family, or peers), occupational (related to work-related situations), social (themes of local, regional, or national interest), and scientific (application of mathematics in science and technology situations or within its own field).

Additionally, for the design of the questionnaire, activities from both multigrade rural textbooks and previous research were used and modified. Subsequently, the table of specifications (**Table 1**) was created, which allowed for the distribution of items according to the considered variables. To establish this relationship, the results of the textbook analysis were utilized, based on the average frequency of each variable. Moreover, recommendations from the literature were considered, highlighting the necessity to include activities from level 3 reading, associated with the task of predicting, due to its significance in graphical

Table 1. Distribution of variables of items & sub-items of questionnaire

Item	Sub-items	Statistical graph	Reading level	Semiotic level	Required task	Context
1	a	Pictogram	1	3	Read	Personal
	b	Pictogram	2	3	Calculate	Personal
2	a	Pictogram	1	3	Read	Personal
	b	pictogram	2	3	Calculate	Personal
	c	Pictogram	4	3	Justify	Personal
3	a	Bars	1	3	Build	Personal
4	a	Bars	1	3	Complete	Personal
5	a	Double bars	1	4	Complete	Personal
6	a	Bars	2	3	Calculate	Personal
	b	Bars	4	3	Justify	Personal
	c	Bars	1	3	Fill in table	Personal
7	a	Points	1	3	Read	Work
	b	Points	2	3	Calculate	Work
	c	Points	4	3	Justify	Work
8	a	Lines	2	2	Calculate	Scientific
	b	Lines	3	2	Predict	Scientific
9	a	Sectors	4	3	Compare charts	Social
10	a	Stem-and-leaf	2	4	Calculate	Work
	b	Stem-and-leaf	4	4	Create question	Work
	c	Stem-and-leaf	4	4	Judge	Work

comprehension (Bustamante-Valdés & Díaz-Levicoy, 2020, 2024). Finally, this questionnaire should contain a total of 10 items, given the type of questions considered for its design.

The questionnaire was validated using the expert judgment method, with specialists in statistics didactics and mathematics didactics (eight in total), who scored each sub-item based on quality, relevance, and pertinence, suggesting wording changes as they deemed necessary. Along with the observations and scores provided, descriptive statistics were used to calculate measures, supplemented by the content validity coefficient (CVC) proposed by Hernández-Nieto (2011). This coefficient establishes the proportional relationship between the average evaluation of the evaluating judges and the theoretical maximum evaluation, as well as the random agreement among the judges, where the value is considered acceptable when it is above 0.70. CVC values of this instrument range between 0.914 and 1.000, indicating an excellent level of validation and internal agreement (Hernández-Nieto, 2011), implying that it is an appropriate questionnaire to be used in a rural multigrade context. Similarly, a pilot test of the instrument was conducted to determine the response time and identify difficulties in understanding the statements. For the administration of this questionnaire, authorization was obtained from the entities involved in the establishments, as well as the signatures of consent and assent from the parents/guardians and students, respectively. All of this was approved and adjusted in advance according to the requirements of the Scientific Ethics Committee of the Universidad Católica del Maule (Resolution Act No. 116/2023).

RESULTS ANALYSIS

Analysis of Reading Levels

In this section, the results regarding items and sub-items associated with the reading of statistical graphs are analyzed according to the levels described by Curcio (1989), Friel et al. (2001), and Shaughnessy et al. (1996), along with the identification of the main errors based on partially correct and incorrect responses from students.

Firstly, concerning the sub-items that require a level 1 reading, responses have been classified according to the following criteria:

- **Correct:** when the data or structural element of a statistical graph is read correctly: the value of the icon in a non-unitary pictogram (1a), the frequency of a variable (2a), and a label based on the data (7a). Additionally, transferring data from a graph to a table, associating the label with its respective frequency (6c).
- **Partially correct:** when errors are made in reading a value not explicitly stated on the axis, leading to imprecise approximations (6c).
- **Incorrect:** when errors are made in reading the value of a non-unitary icon (1a), labels are not associated with their frequency, and sometimes, failing to identify implicit data on the axes (6c), and errors are made in reading labels of the dot plot (7a).

Table 2 presents types of responses corresponding to the sub-items. It is observed that, overall, correct responses predominate (84.1%), well above incorrect responses (10.1%) and partially correct responses (5.7%). Additionally, it is noted that the sub-item with the highest percentage of correct responses is 2a (100%), in contrast to sub-item 6c (72.7%).

In **Table 3**, the errors observed in the sub-items related to level 1 reading are presented. In it, we see that the majority of students make errors in reading values not explicitly stated on the scale (22.7%), followed by not reading the value of the icon

Table 2. Types of responses obtained in sub-items associated with reading level 1

Type of answer	Sub-Items				Total
	1a	2a	6c	7a	
Correct	18 (81.8)	22 (100)	16 (72.7)	18 (81.8)	74 (84.1)
Partially correct			5 (22.7)		5 (5.7)
Incorrect	4 (18.2)		1 (4.5)	4 (18.2)	9 (10.1)
Total	22 (100)	22 (100)	22 (100)	22 (100)	88 (100)

Table 3. Response errors for reading level 1 sub-items

Sub-items	Task	Error	F (%)
1a	Read part of a pictogram	Do not read value of the icon used in the pictogram	4 (18.1)
6c	Pass data between statistical representations	Misreading non-explicit values on scales	5 (22.7)
		Associate the tag with its frequency	1 (4.5)
7a	Read data literally	Read frequencies on a dot plot	4 (18.1)

Table 4. Types of responses obtained in sub-items associated with reading level 2

Type of answer	Sub-items						Total
	1b	2b	6a	7b	8a	10a	
Correct	15 (68.2)	19 (86.4)	14 (63.6)	13 (59.1)	9 (40.9)	18 (81.8)	88 (66.7)
Partially correct	1 (4.5)	1 (4.5)			3 (13.6)		5 (3.8)
Incorrect	6 (31.8)	2 (9.1)	8 (36.4)	9 (40.9)	9 (40.9)	4 (18.2)	38 (28.8)
No answer					1 (4.5)		1 (0.8)
Total	22 (100)	22 (100)	22 (100)	22 (100)	22 (100)	22 (100)	132 (100)

Table 5. Response errors for reading level 2 sub-items

Sub-items	Task	Error	F (%)
1b	Calculate frequencies in non-unitary pictogram	Identify the number of icons without adding them or considering their value	1 (4.5)
		Does not correctly determine total number of icons, but considers value of each of these	2 (9.1)
		Correctly determines the number of icons, but does not consider their value	3 (13.6)
2b	Calculate frequency sum in unit pictogram	Declares the correct values (addens), but does not perform the sum of frequencies	1 (4.5)
		It only declares an addend, it does not calculate frequencies	2 (9.1)
6a	Calculate frequency in horizontal bar graph	It only declares an addend, it does not calculate frequencies	2 (9.1)
		Does not identify missing numerical values on the frequency axis	3 (13.6)
		Declares the correct values (addens), but does not perform the sum of frequencies	1 (4.5)
		Correctly considers the frequencies to add, but makes errors in the result	2 (9.1)
7b	Calculate frequency in dot plot	Makes incorrect calculations when comparing data	9 (40.9)
		Confuse the frequency with the category of the variable	1 (4.5)
8a	Calculate difference in line graph	Identify the values, but fail to calculate the difference	2 (9.1)
		Performs subtraction calculation without apparent meaning	10 (45.5)
10a	Calculate sum in stem-and-leaf plot	Performs incorrect sum calculations	3 (13.6)
		Misidentifies the category of the variable to add	1 (4.5)

used in the pictogram (18.1%), and errors in reading frequencies in a dot plot (18.1%). Finally, with less occurrence, there is an error in associating frequencies with corresponding labels when completing a table from a bar graph (4.5%).

Secondly, concerning the sub-items that require a level 2 reading, responses have been classified according to the following criteria:

- **Correct:** when correctly summing frequencies in pictograms with unitary (2b) and non-unitary icons (1b), horizontal bar graph (6a), and stem-and-leaf plot (10a), making comparisons of data in a dot plot (7b), and finding differences in data from a line graph (8a).
- **Partially correct:** when responses are based solely on declaring the values to be summed (addends), without reaching the total (1b, 2b), or the values to be subtracted, without obtaining the difference (8a).
- **Incorrect:** when obtaining frequencies without considering the value of the non-unitary icon (1b), or making errors in obtaining the sum (1b, 2b, 6a, 7b, 10a) and difference (8a), occasionally declaring only one of the addends, not reaching the sum of frequencies (2b, 6a), and identifying incorrect frequencies to be summed (6a, 7b, and 10a).

In **Table 4**, the types of responses to the sub-items, where a level 2 reading is required are presented. Overall, the responses are mostly correct (66.7%), followed by incorrect (28.8%), and very few are partially correct (3.8%). According to the sub-items, 2b has the highest number of correct responses (86.4%), while sub-item 8a obtains the lowest number (40.9%). Regarding sub-item 8a, it is worth noting that correct responses have the same percentage as incorrect ones (40.9%), and there is one student who does not respond (4.5%).

Table 5 presents the errors observed in students' responses to the sub-items that require a level 2 reading. It becomes evident that the predominance of errors is related to performing simple mathematical calculations. Specifically, errors are observed when finding differences from data presented in the line graph (45.5%) and when making incorrect calculations while comparing data

Table 6. Types of responses obtained in sub-items associated with reading level 3

Type of answer	Sub-Item
	8b
Correct	9 (40.9)
Partially correct	10 (45.5)
Incorrect	3 (13.6)
Total	22 (100)

Table 7. Response errors for reading level 3 sub-items

Sub-items	Task	Error	F (%)
8b	Predict value from data present in line graph	Declare a value without considering the data trend	3 (13.6)
		Declare a value partially considering the data trend	10 (45.5)

Table 8. Types of responses obtained in sub-items associated with reading level 4

Type of answer	Sub-items					Total
	2c	7c	9a	10b	10c	
Correct	18 (81.8)			18 (81.8)	4 (13.6)	40 (36.4)
Partially correct	1 (4.5)	11 (50.0)	7 (31.8)	2 (9.1)	4 (45.5)	25 (22.7)
Incorrect	3 (13.6)	11 (50.0)	15 (68.2)	1 (4.5)	13 (36.4)	43 (39.1)
No answer				1 (4.5)	1 (4.5)	2 (1.8)
Total	22 (100)	22 (100)	22 (100)	22 (100)	22 (100)	110 (100)

(40.9%). Similarly, at times, students correctly determine the quantity of icons but fail to consider their value (13.6%). In addition to facing difficulties in summing frequencies due to not identifying missing numerical values on the frequency axis (13.6%). Similarly, difficulties are evident in sum calculations when considering data in the double stem-and-leaf plot (13.6%).

Thirdly, the classification of responses to the sub-items requiring level 3 reading is presented according to the following criteria:

- **Correct:** The trend of the data presented in the line graph is described, declaring a value within the acceptable range. For example, in this case, the variation in an acceptable weight range fits a maximum value of 65 kg and a minimum value of 55 kg, which can be obtained by considering the average of data that have not had significant variations over the past 15 years.
- **Partially correct:** When the trend of the data presented in the line graph is partially described, declaring a value outside the established range but close to it. For example, 68 kg.
- **Incorrect:** When the trend of the data presented in the line graph is described, responding with values far outside the acceptable range, which is not coherent with the data. For example, 78 kg.

Next (**Table 6**), the types of level 3 reading responses obtained by the students are presented. It is evident, at a general level, that the majority of them respond in a partially correct manner (45.5%) and correct manner (40.9%). Incorrect responses are significantly lower (13.6%).

Regarding the most frequent error when predicting a value from data in a line graph, it is observed that it corresponds to declaring a value while partially considering the trend of the data (45.5%). On the other hand, few students respond with a value without considering the data trend present in the line graph (13.6%) (see **Table 7**).

Finally, the classification of responses to the sub-items requiring level 4 reading is presented, categorized, as follows:

- **Correct:** when they justify correctly by understanding the context and relating it to the data present in the graph (2c and 10c), creating questions based on data from a stem-and-leaf plot, considering their context (10b).
- **Partially correct:** when they fail to fully justify their argument due to lack of information required from a context (2c), not considering the data present in graphs in their arguments (7c, 10c), or with minor contextual errors (7c and 10c), arguing correct statements but with erroneous processes such as changing frequency to percentage (9a), creating incomplete questions or ones that lead to errors due to their possible answers (10b).
- **Incorrect:** when they confuse axis labels when arguing their response (2c), categories (9a), or the way data are represented (9a), as well as the structure required to formulate questions (10b).

As a summary, **Table 8** presents the distribution of response types. It is observed that there are sub-items (7c, 9a), where correct responses are not identified. Additionally, in general, the majority of participating students respond incorrectly to sub-items at this level (39.1%), indicating difficulties in argumentation processes involving statistical graphs. Likewise, the correct response type accounts for 36.4% and partially correct for 22.7%, yielding low results when responding at this reading level. On the other hand, the sub-items with the highest correct responses are sub-items 2c and 10b with 81.8%. Finally, sub-items 7c and 9a yield the lowest amount (0.0%), where dot plots and pie charts interact, which are worked on in higher-level courses.

Regarding the errors made by students when responding to level 4 reading sub-items (**Table 9**), the predominant one is justifying based on data with contextual errors or without considering it in the dot plot (90.9%) and stem-and-leaf plot (77.3%), providing evidence of not understanding real-life situations in their arguments. Similarly, a significant number of students argue without considering the data from the graph, focusing on their personal view in the stem-and-leaf plot (63.6%) and dot plot (59.1%)

Table 9. Response errors for reading level 4 sub-items

Sub-items	Task	Error	F (%)
2c	Justify statement in pictogram	It argues correctly, but it does not consider all the information in the graph	1 (4.5)
		Confuses categories in its justification	3 (13.6)
7c	Justify statement in dot plot	Argues without considering the data in the graph, focusing on his personal vision	13 (59.1)
		Justification based on data with context errors or without considering it	20 (90.9)
9a	Justify by comparing pie charts	Choose the correct graph, but explain the registration change procedure with errors	7 (31.8)
		Select the wrong graph, considering the frequencies as percentages	14 (63.6)
		Selects the wrong graph, where the percentages do not match the actual frequency	1 (4.5)
10b	Create question from data in stem-and-leaf plot	Ask a question that is not consistent with the data	2 (9.1)
10c	Justify statement in stem-and-leaf plot	Argues without considering the data in the graph, focusing on his personal vision	14 (63.6)
		Justification based on data with context errors or without considering it	17 (77.3)

Table 10. Types of responses obtained in sub-items associated with semiotic level 3 & level 4

Type of answer	Sub-items			Total
	3a N3	4a N3	5a N4	
Correct	3 (13.6)	18 (81.8)		21 (31.8)
Partially correct	16 (72.7)	1 (4.5)	11 (50)	28 (42.3)
Incorrect	3 (13.6)	3 (13.6)	11 (50)	17 (25.8)
Total	22 (100)	22 (100)	22 (100)	66 (100)

to justify their responses and considering frequencies as percentages (63.6%), implying that they make errors when selecting the pie chart that represents the data from a statistical table.

Semiotic Level Analysis

In this section, we describe the results of the responses provided by students regarding the items and sub-items that require constructing and completing bar graphs, considering semiotic level 3 and level 4. The constructions have been classified according to the following criteria:

- **Correct:** Constructions that represent the data from a table, incorporating all elements of the statistical graph correctly (3a), as well as only titles and bars in completion tasks (4a and 5a).
- **Partially correct:** When minor errors are made in both elaborating graph elements and using different spaces between bars, and partially representing the data from a statistical table (3a, 4a, and 5a).
- **Incorrect:** Major errors are observed, involving several elements of the statistical graph. For example, using different spaces in specifiers and occasionally not representing the data from statistical tables (3a, 4a, and 5a).

In **Table 10**, it can be observed that the majority of students respond to these sub-items in a partially correct manner (42.3%), with this type of response predominating in sub-item 3a (72.7%). Additionally, it becomes evident that sub-item 4a has the highest number of correct responses (81.8%), showing a significant difference from sub-items 3a (13.6%) and 5a (0.0%), with both partially correct and incorrect responses distributed equally in the latter (50.0%). In the sub-items of semiotic level 3, difficulties are evident in sub-item 3a, with a low number of correct responses (13.6%) compared to 4a (81.8%). This situation is explained because in the first sub-item (3a), students must construct all elements of the statistical graph. In contrast, in the second sub-item (4a), students must complete a construction, where they only need to add the title and create the bars in predetermined spaces, posing less difficulty due to the fewer elements required for the task.

According to the errors observed in constructing a bar graph (3a), the most frequent one is not assigning titles to the axes (77.3%), followed by not defining the frame of the graph (59.1%) and not using the same space between bars (59.1%). Regarding completing a graph with titles and bars (4a), the most common mistake is not assigning a title that represents the data (54.5%) and not using the same space between bars, even though the corresponding space is pre-established (31.8%). Finally, concerning completing a double bar graph with titles and bars (5a), similar to the previous one, the predominant error is not correctly assigning the graph's title (54.5%), followed by using different spaces between bars (36.4%), and separating double bars within the same category (22.7%) (see **Table 11**).

CONCLUSIONS

From the analysis of 5th and 6th grade students' understanding of statistical graphs at five rural multigrade schools in the Maule Region, Chile, we can draw the following conclusions:

Firstly, concerning reading levels, students generally encounter no significant issues with level 1 sub-items, which aligns with previous findings on the use of pictograms (Batanero et al., 2018; Hernández et al., 2021), line graphs (Arteaga et al., 2021), single and double bar graphs (Hernández et al., 2021; Rodríguez, 2019), and pie charts (Rodríguez, 2019). However, these results contradict those reported by Díaz-Levicoy and Batanero (2020) for 6th grade students, although it is important to note that their study utilized graphs with two data distributions, making the task more complex. Additionally, the most common error observed in this study is reading values not explicitly stated on scales, similar to Díaz-Levicoy and Batanero (2020). Therefore, we

Table 11. Response errors for semiotic level 3 & level 4 sub-items

Sub-items	Task	Error	F (%)
3a	Build a simple bar graph	Does not define the graph frame	13 (59.1)
		Does not assign a scale	9 (40.9)
		Does not assign titles to the axes	17 (77.3)
		Incorrectly places category labels	5 (22.7)
		Total or partial absence of labels	3 (13.6)
		Bars not attached to the axis or centered in a graph space	9 (40.9)
		Disproportional space between bars	13 (59.1)
		Poorly graduated scale	6 (27.3)
		Disproportional or poorly constructed bars	6 (27.3)
		Confuses frequency with category	1 (4.5)
4a	Complete a simple bar graph (title and bars)	Does not correctly assign the graph's title	12 (54.5)
		Disproportional space between bars	7 (31.8)
		Disproportional bars	2 (9.1)
		Assigns frequency inside the bars	2 (9.1)
		Bars not attached to the axis or centered in a graph space	2 (9.1)
5a	Complete double bar graph (title and bars)	Does not correctly assign the graph's title	12 (54.5)
		Separates double bars within the same category	5 (22.7)
		Assigns frequency inside the bars	2 (9.1)
		Disproportional space between bars	8 (36.4)
		Omits the representation of one or more frequencies	3 (13.6)
		Disproportional bars	1 (4.5)
		Assigns labels on the bars of the categories	1 (4.5)

recommend designing activities that enable students to identify implicit data through various statistical representations, a fundamental aspect of graph reading.

Regarding level 2 reading, students respond with greater difficulty, unlike Batanero et al. (2018) but consistent with Rodríguez (2019). The most frequent errors are related to performing mathematical calculations when seeking the sum or difference between quantities. It is advisable to reinforce the use, understanding, and contextual importance of simple algorithms to improve the reading of statistical graphs, especially in subtraction, where the greatest difficulties arise. The importance of students understanding these algorithms lies in its benefits for the interpretation process, as it allows for obtaining more accurate information and, therefore, better understanding of the data. This fosters skills to identify errors and inconsistencies in these statistical representations.

Concerning level 3 reading, students demonstrate important difficulties, with a low proportion being able to respond while considering all the data present in the graph, leading to errors in predicting contextualized values without considering the data trend. These low results partially correlate with Rodríguez (2019), who also reported failures at this level. Hence, it is necessary to emphasize data prediction with students to promote understanding of its importance in identifying trends, estimating values, and ultimately improving decision-making based on graphical representations.

Regarding level 4 reading, participants in this study face important difficulties, with the majority responding incorrectly. This is because they justify their answers with contextual errors, indicating a lack of clarity about real-life situations or an inability to connect them with the information presented in the statistical graph. When compared to previous research (Batanero et al., 2018; Rodríguez, 2019), there is agreement in the low results at this level. Therefore, it is suggested to promote understanding of data context and argumentation processes when working with statistical graphs, enabling a critical analysis of information collected from real-world situations. Considering reading level 1 and level 2, it is concerning that students make these errors, as they are addressed from the early years of schooling and are fundamental for the acquisition of later levels.

Regarding the construction of bar graphs and associated levels of semiotic complexity, particularly at level 3, significant difficulties are observed in the construction process, consistent with previous research reporting challenges in scale design, absence of titles, and uneven spacing between bars. This situation can be explained by the difficulty in organizing the structural elements involved in correctly constructing a statistical graph. Therefore, it is essential to focus on learning about these elements to enable students to communicate results effectively.

Finally, in tasks involving level 3 semiotics, most students do not encounter significant difficulties and respond correctly. However, the main challenges involve not using a title representing the data and having bars with different spacing, similar to Cruz (2013). Additionally, when completing a graph with two data distributions, apart from the aforementioned difficulties, students separate double bars within the same category, complicating the reading and understanding of the double bar graph. It is recommended to emphasize the importance of correctly using double bars for optimal reading of these statistical diagrams representing two data distributions. Comparing results with previous literature, it appears that rural school students make the same errors as students attending urban schools. This situation could be a subject for future research.

Based on the above, it is projected to design training activities to enhance the learning of students attending multigrade rural schools concerning reading and constructing statistical graphs using relevant aspects of their context. Similarly, analyzing the graphical comprehension of a larger number of participants, considering a quantitative analysis, is suggested. Finally, utilizing different types of graphs in other activities to supplement this study with more information, such as constructing line graphs or pie charts, is recommended.

Finally, as recommendations for researchers in this field, consider the advantages of multi-grade settings, where students of different educational levels can access the same mathematical objects. Therefore, it would be a valuable contribution to propose activities that enhance learning by focusing on the individual capabilities of each student.

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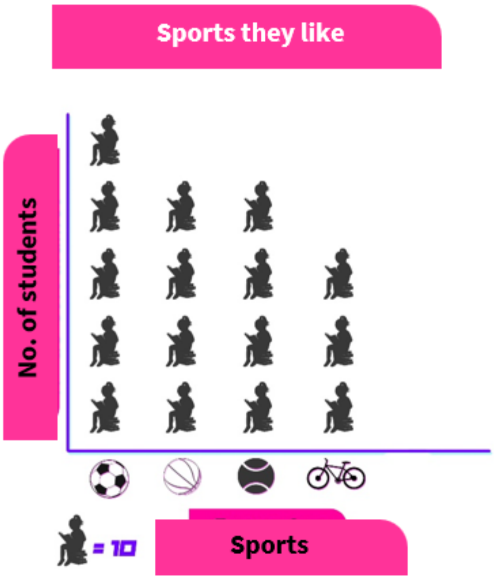
APPENDIX A: QUESTIONNAIRE

Item 1

The following pictogram shows the results of a survey about the favourite sports of the students in a school: soccer, basketball, tennis, and cycling. ***Look at the graph and answer:***

- **How many students does each icon represent to depict the frequencies?**

- **How many students in total participated in the survey?**



(Adapted from MINEDUC 1°, 2014, p. 21)

Item 2

A group of friends conducts a vote to determine their favourite animal. **Look at the graph and answer:**

a) How many friends voted for the horse?

b) How many friends voted for chicken and duck in total?

c) A friend claims that the duck is the least voted for. Do you think this statement is correct based on what the pictogram shows? Justify your answer.

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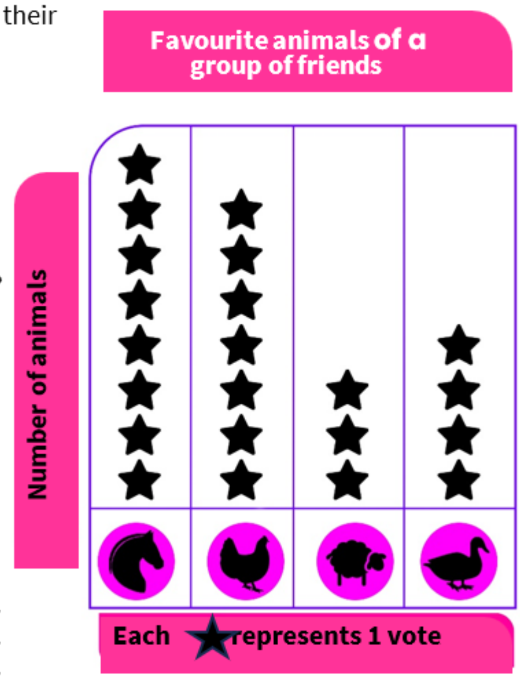


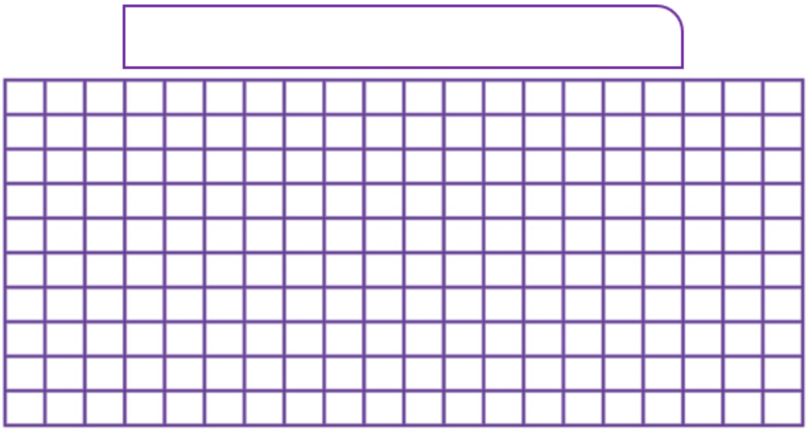
(Adapted from MINEDUC 1°, 2021. p. 78)

Item 3

A survey was conducted with a group of friends about their preference for sports clubs, and the results were recorded in the following frequency table.

a) Look at the frequency table and then construct a bar graph, writing the title, axis, labels, and scale.

Sports Club	Frequency
COLO COLO	7
U	5
C D U C	4
CURICO UNIDO	3



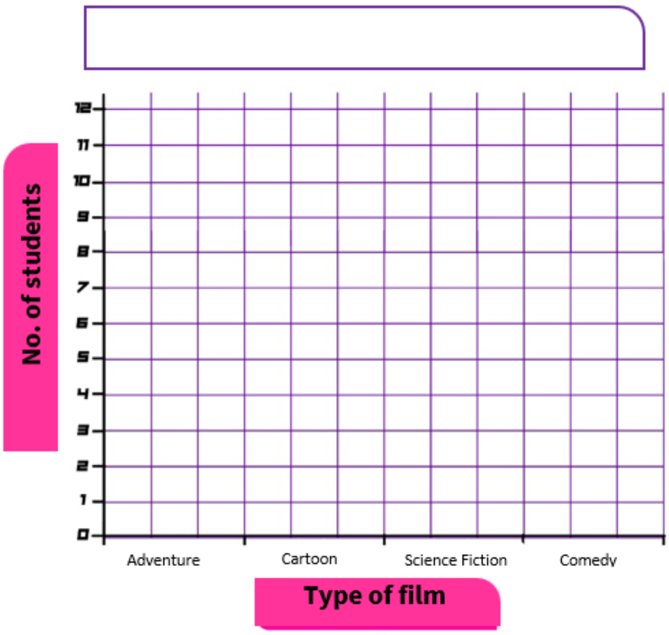
(Adapted from MINEDUC 1°, 2014, p. 27)

Item 4

In the following table, the results of a survey on the type of movie liked by a group of students are shown.

a) Look at the table and complete the bar graph.

Type of Film	Frequency
Adventure	5
Cartoon	5
Science Fiction	5
Comedy	10



(Adapted from MINEDUC 3°, 2014, p. 26)

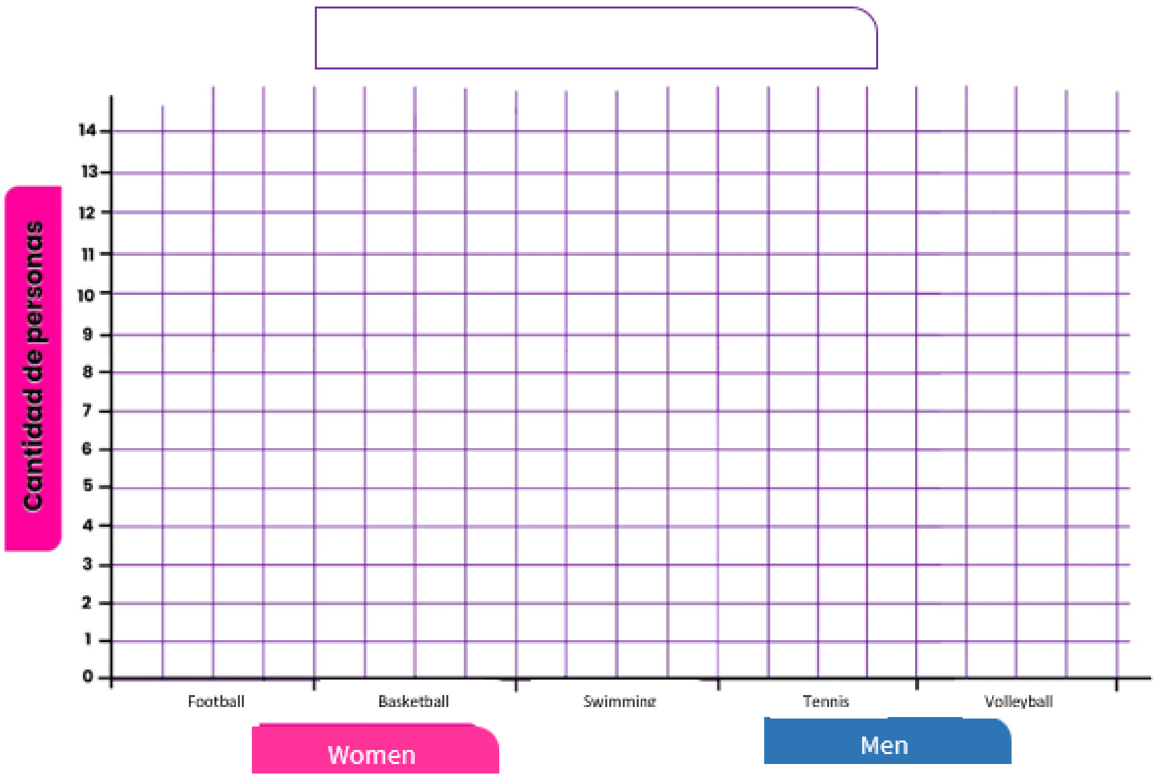
Item 5

Rocío conducted a survey with her friends asking 'What sport do you play?' Each one gave only one response, which was represented by a dot (●)

Sports practiced by Rocío's friends

Sports	Women	Men
Football	● ● ● ● ● ● ● ●	● ● ● ● ● ● ● ● ● ● ● ●
Basketball	● ● ● ● ●	● ● ● ● ● ●
Swimming	● ● ●	● ● ● ●
Tennis	● ●	● ● ●
Volleyball	● ● ● ●	● ● ● ● ●

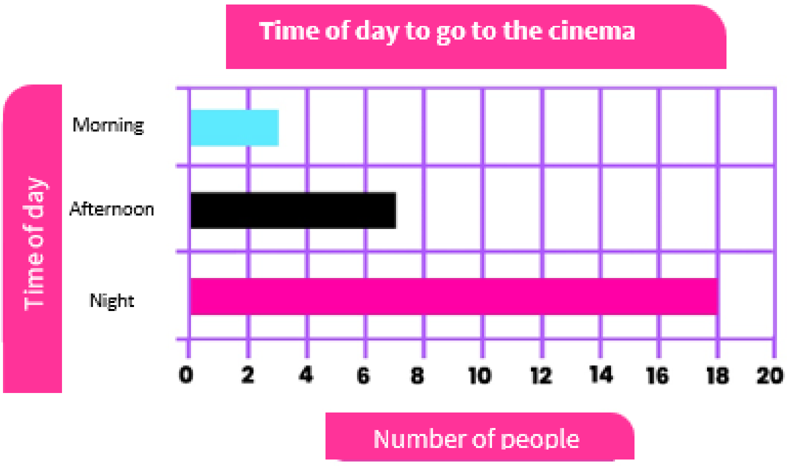
a) With the information from the table, complete the double bar graph.



(Adapted from MINEDUC 4°, 2021, p. 64)

Item 6

The following graph shows the frequency of a group of people regarding their preferred time of day to go to the cinema.



a) **How many people in total prefer to go to the cinema in the morning and afternoon?**

b) **Pedro came to the conclusion that night is the preferred time for people to go to the cinema. Is this conclusion valid? Why?**

____

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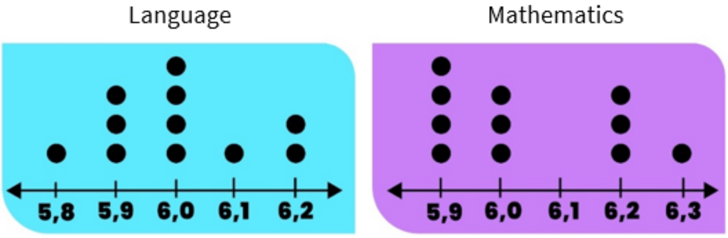
c) **Complete the following table with the data from the bar graph.**

Time of day	Number of people

(Adapted from Galileo, 2014, p. 262)

Item 7

In the teachers' council of a school, they discuss the difficulties that students face in mathematics and language subjects. The following diagrams correspond to the grades (between 1.0 and 7.0) obtained by the sixth-grade students in mathematics and language.



a) In the Language subject, what grade was obtained by only two students?

b) How many students scored more than 6.0 in Mathematics?

c) One teacher says that the mathematics subject is harder than the Language subject because there are fewer children with a grade of 6.0 or higher. Do you agree? Why?

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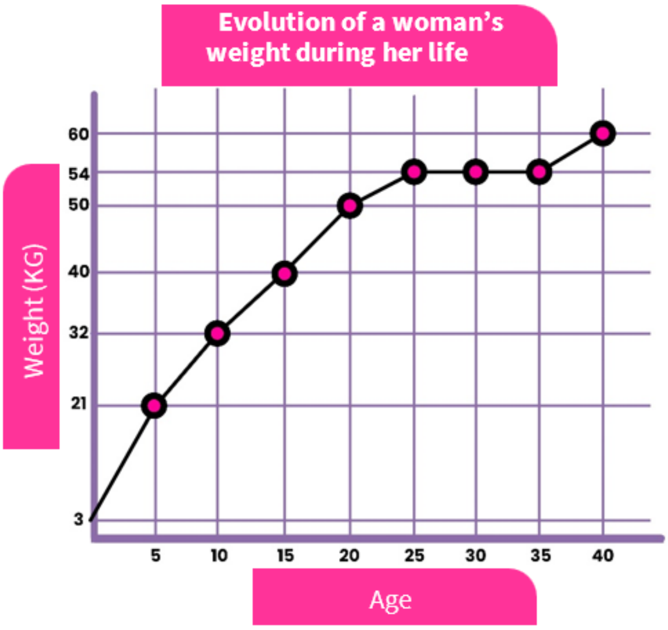
(Adapted from Santillana 6°, p. 293)

Item 8

The following graph represents the evolution of a woman's weight (mass) up to the age of 40.

a) What is the difference between the weight the woman had at 15 years old and 25 years old?

b) Imagine the graph shows the woman's weight at the age of 45. What weight would she have?



(Adapted from Walichinski & Santos Junior, 2013)

Item 9

The mayor of the city of Talca conducts a survey among some residents to inquire about the means of transportation they use. The results are shown in the following table:

Means of transportation	Frequency
Shared taxi	250
Bicycle	100
Car	200
Bus	450

a) Which graph best represents the information in the table? Justify your choice.

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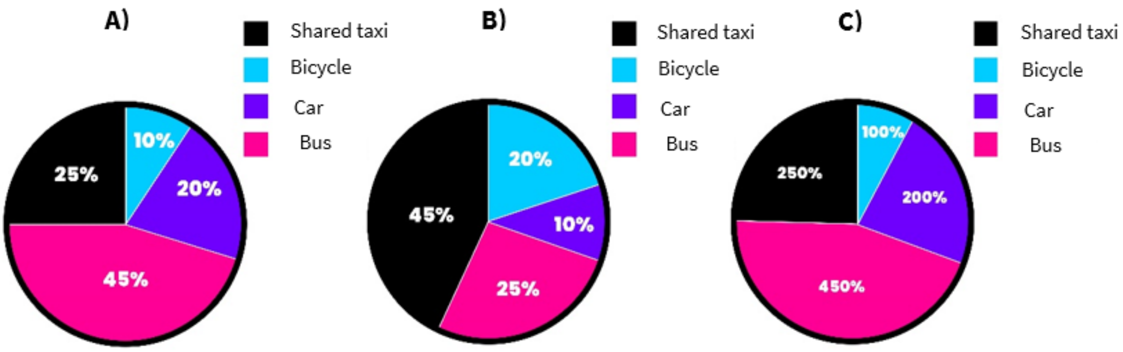

(Source: Authors' own elaboration)

Item 10

In the company 'Laguna Azul,' they decided to record the ages of their workers in a stem-and-leaf plot. Analyse the plot and respond.

Leaf (Ages of women)	Stem	Leaf (Ages of men)
7 7 5 5 4	2	3 3 5 6 8 8 9 9 9
9 9 8 6 4 4 3 1 1	3	1 2 2 3 5
8 7 7 5 4 4 0	4	1 3 3 3 5 6 7 7 6
9 8 8 6 4 2 1 0	5	0 1 3 4 4 5

a) How many women are there in the company?

b) Create a question that can be answered using the information from the stem-and-leaf plot.

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c) The company owner offers a retirement incentive to people who turn 60. Is this policy effective according to the data in the plot? Why or why not?

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(Adapted from MINEDUC 6°, 2021, p. 121)