STATISTICAL LITERACY DEVELOPED BY STUDENTS AT THE END OF THE HIGH SCHOOL

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In this article we report the results of research with Mexican students whose objective was to know the degree of development of statistical literacy that they have achieved throughout their basic and upper secondary education. The instrument used is an online questionnaire that has been adapted from various items in the literature and some of our own creation. The results indicate that students have low levels of statistical literacy in graphic representations and descriptive measures, even though they are themes of the curriculum from primary education; the results are even lower for correlation, box plot, decile, and probability items.

INTRODUCTION

The central objective of statistics has long been to provide methodological support to other disciplines (e.g., economics, biology, engineering) because it is the science that studies data collection, analysis, and interpretation methods. This cross-sectional nature of statistics has earned it recognition and has been one of the reasons why it has reached the university curriculum. From the great development of digital technologies, data and chance have extended their scope beyond professions and science, and have become omnipresent in modern society (Ridgway, 2016), statistics thus acquires a new dimension: as a tool for the quantitative literacy of citizens. In this new context, statistics reach the basic and high school curriculum.

From a methodological perspective, teachers generally focus their teaching on students understanding the formulas and procedures that underlie statistical methods to develop calculations and solve problems, either manually or with the help of some software; on the other hand, when statistics is seen as a literacy tool and more than the mastery of formulas and procedures, the central objective is the development of skills to understand, interpret, reflect, and critically evaluate statistical information that relate to various aspects of the citizens' lives and the development of society (e.g., security, economy, health, politics), which is featured in the media and government reports (Watson, 2006).

In this context, in the present work, we have proposed to investigate the statistical literacy that Mexican students have achieved at the end of high school studies, with the purpose of knowing to what extent the courses they have taken allowed them to develop this ability that is considered essential in the educational formation of the citizens of today's society.

CONCEPTUAL FRAMEWORK

Wallman (1993) raises one of the first definitions of statistical literacy: "ability to understand and critically evaluate statistical results that permeate daily lives" (p.1). Gal (2002) proposes a conceptualization of statistical literacy in the context of adult education and defines a model for its analysis and development in the classroom, starting from the identification of two interrelated components:

- People's ability to interpret and critically evaluate statistical information, data-related arguments, or stochastic phenomena that they may encounter in diverse contexts.
- Ability to discuss or communicate their own reactions to such statistical information that includes their understanding of the meaning of the information, their opinions about the implications of this information, or their concerns regarding the acceptability of given conclusions.

In accordance with this, he proposes a statistical literacy model that consists of two main components: knowledge and dispositions. Knowledge includes general literacy skills, statistical knowledge, mathematical knowledge, context knowledge, and critical questions, and dispositions include beliefs and attitudes as well as a critical stance.

Callingham and Watson (2017) conceptualize statistical literacy as a construct of three hierarchical levels: basic understanding of statistical and probability terminology, understanding of language and statistical concepts integrated in the context of a social discussion, and an attitude of questioning statistical conclusions and results.

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RESEARCH BACKGROUND

Statistical literacy is a topic that has gained prominence in recent years. In a study with Chilean teachers in practice and in training, Rodríguez (2017) evaluated teachers' levels of statistical literacy and their attitudes towards statistics. The results show that in general the teachers presented low level of statistical literacy on textual situations and made implausible arguments with basic statistical concepts.

Averages are another statistical concept that is used very often to summarize statistical information. Mayen et al. (2007) in an investigation with Mexican high school students, identified the following difficulties: recognizing the median as the best average of ordinal data, calculating weighted means, understanding the definition of median and weighted average, and identifying that the mean is very sensitive to extreme data.

Galesic and García-Retamero (2010), in a large comparative study on the level of statistical literacy with citizens of Germany and the United States to interpret statistical information in the health area, found a large gap in statistical skills among people with low and high educational level; as a result, many patients may not understand relevant information to make informed decisions.

Meanwhile, Inzunsa and Juárez (2014) report various difficulties that high school teachers have when reasoning with basic statistical concepts. The teachers showed a superficial and isolated understanding of statistical concepts, such as the interpretation and conversion of various graphical representations, measures of central tendency, and measures of variability. In the same way, Inzunza (2015), in an investigation with college students on their abilities to interpret graphs with data from economic and sociodemographic contexts, found that students were located fundamentally at the idiosyncratic and basic reading levels, the two lowest of the taxonomy proposed by Aoyama (2007) (idiosyncratic, basic graph reading, relational, critical, and hypothesizing) to rank the level of graph interpretation of students. The college students' interpretations were mainly focused on local aspects of the graphs, and they had difficulty relating relevant information with the context.

METHODOLOGY

The instrument we constructed consists of 12 multiple-choice items, which contemplate issues of data collection, organization and representation of data, and descriptive measures. The instrument can be seen at the following link (https://tinyurl.com/Statistical-Literacy). The study subjects were 193 students who had recently completed high school in Mexico. Their statistical background was very diverse, because, although the basic education curriculum is the same for all, the high school curriculum is not. In some curricula for this level, the study of statistics is not even contemplated.

RESULTS AND DISCUSSION

Data Collection

Table 1 shows the percentage of students who chose each option per item on data collection.

Table 1. Percentage of answers in the data collection items (* indicates correct response)

Item	A	B	C	D
1	37.8	10.4	51.8*	
2	13.5	83.4*	3.1	
3	45.1	24.9	30.1*	
4	16.1	32.1	51.8*	
5	26.4	57*	8.3	8.3
6	68.4*	5.7	10.9	15

Item 1 was intended for the students to identify the sample and the population from a survey situation, two concepts that at first glance do not offer greater difficulty. However, only 51.8% answered the sample and population correctly, as displayed in Table 1. Item 2 was intended to identify whether a given situation corresponded to an observational study or an experimental study. The item proved to be simple because it was answered correctly by 83.4% of the students. Item 3, which was intended to judge the validity of a generalization to a population based on data from a non-random sample, turned out to be a difficult one on this topic. The objective of item 4 was to assess whether the students attributed the

variability of the mean of two samples from the same population to their construction, or on the contrary, attributed it to other factors such as sample size and representativeness. The item was answered correctly by just over half of the students. Item 5 was developed to evaluate the students' knowledge regarding the design conditions of a statistical experiment to obtain valid data, and 57% of the students correctly considered a random assignment of the subjects to the treatments. Item 6 had the purpose of evaluating whether students consider the selection of a random sample as the best option to allow generalizations about a population; the item was answered correctly by 68.4% of the students.

Organization and Representation of Data

Table 2 shows the percentage of students who chose each option per item on organization and representation of data.

Table 2. Percentage of answers in the organization and data representation items (* indicates correct response)

Item	A	B	C	D
7	32.6	24.4	43*	
8	20.7	14	22.8	42.5*
9	16.6*	17.1	18.1	48.2
10	14.5	21.8	18.1	45.6*

Item 7 provided two dot plots, one with the weights of one rock sample, and the other with the mean weights of various rock samples. A point with the same value on each graph was circled; the purpose was for students to identify the difference between them. Although 43% of the students recognized the difference, 32.6% considered that the circled points represented the same measure (Table 2).

Item 8 consisted of interpreting a histogram with the times that students in a school connect to the internet daily. Attending to properties of shape, extreme data, average, and variability, 42.5% of the students answered correctly. The other options contained partial descriptions of the graph in colloquial form. Item 9 also consisted of a histogram that represented the number of confirmed cases of COVID-19 in Mexico, considering gender and age. Among various interpretations of the graph, the one that was incorrect was requested (many more men than women have been infected with COVID-19 in Mexico); only 16.6% of the students chose this answer. Item 10 also had a COVID-19 context. The correct answer contemplated that to make comparisons it was more appropriate to consider the size of the population of the countries, and not only the absolute frequencies as reported by a newspaper; only 45.6% of the students answered correctly. To solve this item, statistical knowledge was necessary, but students were also required to take a critical attitude to question the information presented in the media.

Descriptive Measures of Data

Table 3 shows the percentage of students who chose each option per item on descriptive measures of data.

Table 3. Percentage of answers in the items of descriptive measures of data (* indicates correct response)

Item	A	B	C	D
11	17.1	21.8	19.2*	42
12	18.7	28	39.9*	13.5

Item 11 proposed that students identify the meaning of a decile, based on the statement: "a student obtained a score on an exam that places him at the 9th decile of the chemistry class." As seen in Table 3, the item was answered correctly by only 19.2% of the students, possibly because it is a topic that appears in the last part of the study program in the high school curriculum, and in some programs where only one course is taught. Item 12 consisted of relating a graph with the number of confirmed COVID-19 cases by age group with another graph that showed compensation for medical expenses for

COVID-19 patients. To answer this item, a visual analysis of the trends of the variables in both graphs was necessary. The correct answer was "the correlation between the number of confirmed cases by age group and the compensation is positive, because the more confirmed cases there are, the more medical insurance compensation is paid or vice versa," which was selected by only 39.9% of the students. As in the case of deciles, the issue of correlation, although it has been incorporated into the curriculum in recent reforms, is a subject of study beginning in high school.

CONCLUSIONS

The results show that the students developed a low level of statistical literacy in their basic education and high school, which is consistent with the results of other research studies (for example, Inzunsa & Juárez 2014; Mayen et al., 2007; Rodríguez, 2017). Among the results, the poor understanding of the representativeness of a sample compared to its population, the lack of understanding of the part-whole relationship and the reading and interpretation of histograms stands out. In addition, due to the results in the items where students were asked to select the wrong answer option, it is pointed out that there is a low level of reading comprehension, which is a fundamental skill for statistical literacy (Gal, 2002).

The topics of correlation, box plots, and deciles are new to the high school, and the focus of instruction is on construction (Inzunza, 2015), leaving aside analysis and interpretation, which affects performance. The results of the research suggest a needed revision of the study programs to incorporate a teaching methodology that promotes the development of statistical literacy that goes beyond calculation and focuses on the interpretation and critical reflection of statistical information as well as understanding of the methods and their foundations for solving problems.

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