Elementary school teachers' comprehension of graphical representations of data

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Abstract

The preliminary results of an empirical research (n 150) on teachers' comprehension of graphical representations of data are presented. A questionnaire consisted of 10 graphical representations with three questions each (in multiple choice format) was used in order to reveal what teachers comprehend of various formats of graphs and diagrams that represent data collected by small statistical surveys and projects. In most of the displays, teachers exhibited major difficulties predicting from the graph ("reading beyond and behind the data") while they were proficient at extracting specific values ("reading the data") and computation types of questions ("reading between the data"). Findings of a similar research on pupils' understanding of graphs are used in comparison with the results. Implications for teacher preparation are discussed.

Key Words: graphs, data displays, primary school, teacher

1. Introduction

Graphical representations of data are an object of study and interest at all levels of statistics education. Quantitative information is increasingly prevalent in our world and students as well as adults should be prepared to read, interpret and use this information in various contexts (Gal, 2002). Reforms in statistics curriculum, during last decade, have stressed the need for better instruction (NCTM, 2000). Whether primary school teachers have the requisite knowledge to teach statistical content effectively is an important consideration. What is the understanding in the area of data displays? In order to ensure that primary school teachers are prepared to teach statistics we should explore the current status of their knowledge.

There has been limited research undertaken on primary school teachers' comprehension of data representations (Jacobbe & Horton, 2010, Espinel et al, 2008)..

The theoretical work related to describing various levels of comprehension of graphs (Curcio, 1987; Friel et al., 2001) suggests that there are three levels of comprehension. Curcio adapted a framework intended to describe general discourse concerning the mathematical relationships expressed in data displays. Graph comprehension is defined as readers' ability to derive meaning from graphs. Different levels of questions can evoke different levels of comprehension. For example, elementary questions about the data represented in a graph requires direct extraction of information from the data (reading the data), intermediate questions require finding relationships in the data (reading between the data), and advanced questions require interpolating and extrapolating (reading beyond the data).

Working as teachers in primary schools we usually face a hard reality regarding several issues that for some is considered ideal. Many colleagues struggle with basic concepts, especially in statistics. Having that context in mind, we decided to find out what our teachers know and can comprehend out of graphical representations in order to organise specific interventions.

2. Methodology

To determine whether in-service primary school teachers were able to correctly read and interpret data representations we used a questionnaire consisted of 10 graphical representations with three questions (multiple choice formats) in each display, representing the three levels of comprehension (within the bounds of possibility).
We used all well known graphical representations (except scatter plot) in order to form a whole picture and to have comparative results.
The simplest question (usually the first one) represented by the identification of specific data points or by the comparison two or more data points and engaged subjects to the extraction of explicit information for which the obvious answer was in the graph (e.g. In a bar graph representing Birth month of students: "How many children were born on April")
The second question represented by the need of summing data and was integration questions. This type required from the reader to consider multiple data points and then to integrate (interpolate) the information using some sort of intellectual function (defining trends for example) and to find relationships (e.g. "According to the information depicted on the graph, which of the following is true")
The most difficult question was the one that required from the reader to extract inferences and predictions. The desirable information was not explicitly depicted on the graph thus the subject must extrapolate in order to extract or predict it (e.g. "Which is the probability for a child to be born in May")

The 10 graphical representations (and the data) that were used are:

1. Bar graph A (vertical): the birth month of a 1000 students
2. Bar graph B (Horizontal): average distance that needed for a car to stop
3. Line plot: which ice-cream flavour do we like
4. Pie chart: TV viewing on the week 5-12/9
5. Line graph: average monthly temperature, rainfall & humidity in Thessaloniki
6. Histogram: height of students aged 10-12 years old
7. Box-plot: results on a mathematics test in three classes (Jacobbe & Horton, 2010)
8. Stem-and leaf plot: time (in sec) that 6^{th} graders
9. Pictograph: the soaring price of oil (Schmid, 1983)
10. Two-way table: energy consumption in USA (Wainer, 1997)

We used data that have collected from small projects in our school, from our pilot implementation of "census at school" and from out of school content (pictograph and two-way table). Teachers were asked to commend at the end of questionnaire regarding the task.
The sample was 150 in-service primary school teachers of the metropolitan area of Thessaloniki, Greece (mainly from our and neighbouring schools).

Sample				
Sex		Service (in years)		
Male	Female	0-10	11-20	21-30
41%	59%	28%	32%	40%

3. Results

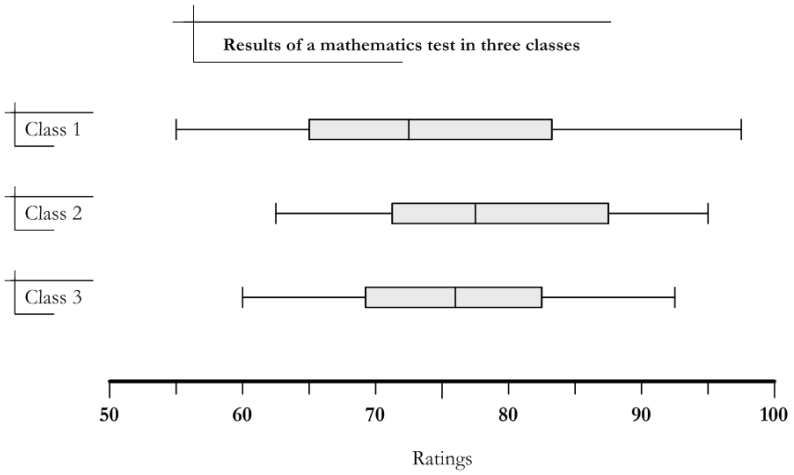
The task was quite demanding. At average, subjects completed the task in a half an hour, showing mixed feelings, denial at the beginning (mainly because of the size of the questionnaire) but interest at the end (in the commends most of them were very positive and asked for a copy to use it in class). Their feedback urged us to continue the research and to have a sample of at least 250 teachers.

So, our analysis is still at first stage and limited to descriptive characteristics. Table 1 shows the percentage of correct answers to the questions that represent the three levels of comprehension.

Graph	Level 1	Level 2	Level 3	No response
Bar graph A	95%	90%	58%	2%
Bar graph B	82%	56%	52%	3%
Line plot	90%	95%	55%	1%
Pie chart	91%	85%	52%	3%
Line graph	80%	30%	74%	6%
Histogram	82%	42%	65%	2%
Box-plot	9%	75%	59%	3%
Stem-and-leaf plot	41%	23%	30%	48%
Pictograph	36%	50%	17%	3%
Two-way table	90%	41%	73%	1%

Table 1: Percentage of correct answers - Teachers

Even from these simple frequencies of empirical data, someone can easily notice important facts that either support other findings in similar research, or supported by relevant literature.
Vertical bar graph, line plot and pie chart are easier to comprehend, while box-plot, stem-and-leaf plot and pictograph are the hardest.
There is a quite large difference between the two bar graphs in all levels (maybe due to data depicted and questions asked).
By far, stem-and-leaf plot had the lowest percentage of correct answers in all levels of comprehension. Also, in the same plot there was an impressive no response rate, almost one out of two subjects chose not to answer, or didn't understand the information depicted on the graph.
In the first question of box-plot (Which was, for Class 1, the best score) the vast majority of subjects (83%) chose the third quartile, 83 points!

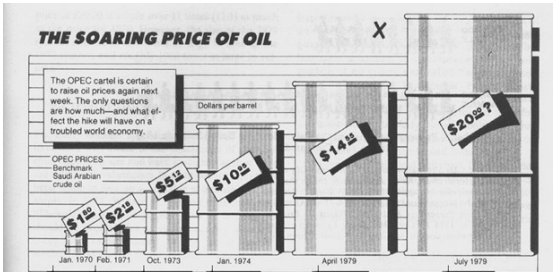


Picture 1: Box plot used

In the same question that asked to primary school students (Michalis, 2006) the percentage of correct answers were higher (4^{th}-25%, 5^{th}-53%, 6^{th}-63%) only because the specific data points were depicted on the graph!

Similarly, in pictograph and to the first question "*In which period there was the largest increase in the price of oil*" teachers seemed confused:

a. Between Jan. 1970 and Feb. 1971 **4**%
b. Between Fe. 1971 and Oct. 1973 **36**%
c. Between Oct. 1973 and Jan. 1974 **27**%
d. Between Apr. 1979 and Jul. 1979 **33**%



Picture 2: Pictograph. *In which period there was the largest increase in the price of oil*

4. Discussion – conclusions

The preliminary results suggest that in-service teachers have quite similar performance (at least in order of better comprehended representations) with students of primary school. In similar research (Michalis, 2006) to primary school students (aged 10 to 12) we've had the following results (Table 2). This needs to be further examined of course.

Graph	Mean score of correct answers (6 questions)
Bar graph A	4,28
Pie chart	4,24
Two-way table	3,65
Line plot	3,43
Histogram	2,86
Line graph	2,85
Pictograph	2,89
Stem-and-leaf plot	2,55
Box-plot	2,43

Table 2: Mean of correct answers 4^{th} – 6^{th} graders (Michalis, 2006)

Teachers struggled with data displays with which were not familiar (e.g. box plot, stem-and-leaf plot and pictograph). Similar results found on Jacobbe & Horton research (2010). Almost all teachers commended on these displays similar to Jacobbe & Horton research (haven't had any experience with that displays etc.) even though asked for more information about them.
As Wu (2004) found, students had difficulties with proportionality in a pictograph. We found the same in teachers, as in the question that had to do with comparison of proportions (Picture 2), only 36% were correct.

Obviously further analysis is needed in order to conclude and discuss implications and inferences. As we mentioned, we are going to continue our research by having more subjects in our sample (target is 250 teachers), by interviewing 10 of them and by implementing an intervention in our school.

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