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Investigating adults' statistical literacy in a Second Chance School through the teaching of graphs

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Abstract

Based on the significance of graph comprehension within statistical literacy, we present the findings of a study that took place in a Second Chance School in Greece. Our aim was to assess the progress of adults' comprehension of graphs. In order to offer to our adult students tasks with realistic context we used graphs, published in the media, some of them being potentially misleading. Our results showed that some of the adults have managed to move from the mere reading of the graphs to their interpretation. However, their critical sense was not so well developed since they often based their interpretations on their dispositions and not on their statistical knowledge.

Key words: statistical literacy; adult students; graph comprehension; Second Chance School

Introduction

The skills that adults need in order to solve everyday problems which contain mathematical and statistical elements has been a topic for research over the last decades (Tout & Gal, 2015). This research area, which might be called Adult's Mathematics Education or Adults Learning Mathematics, can be placed in the borderland between mathematics education and adult education (Wedege, 2010). According to Wedege, its key concept is numeracy and the research field is related to adults, mathematics and lifelong education in a societal context. This means that there are different kinds of adult education settings (Evans, Wedege & Yasukawa, 2013), like adults' basic education (ABE) either in formal or informal contexts.

Acknowledging the importance of a modern citizen's ability to interpret visual data coming from the media, especially data representing statistical information, we organised a study with adults studying in a Greek "Second Chance School" (SCS), described more fully below. In particular, our aim was to monitor the progress of adults' statistical knowledge during the teaching of basic statistical concepts.

Although there are studies about students' graph comprehension in secondary education (e.g. Aoyama, 2007) or tertiary education (e.g. Monteiro & Ainley, 2007), there are not studies about students in adults' basic education programs. In this paper we focus on the adult students' graph comprehension and how this develops when they have to interpret media graphs and misleading graphs. Our research questions were formulated as follows:

- What is the students' level of graph comprehension?
- Do students demonstrate a critical sense towards the statistical information presented by the graphs?

Numeracy and Statistical literacy

Although it is not easy to discriminate between the different notions of numeracy, it is a fact that numeracy can serve as a connection between mathematics and adult life (Evans, Wedege & Yasukawa, 2013). Similarly, Dalby (2017) concludes that numeracy does not refer to a simplified type of mathematics but concerns the way a person uses it. Developing the analysis, four dimensions of "numerate behavior" were identified for the PIAAC survey:

> (a) context (everyday life, work, societal, further learning), (b) response (identify/locate/access (information); act on/use; interpret/evaluate, (c) mathematical content (quantity and number, dimension and shape, pattern and relationships, data and chance) and (d) representations of mathematical/statistical information for example text, tables and graphs
>
> (EVANS, 2014, pp. 39-40, citing OECD, 2012).

Among these dimensions there are direct references to statistical knowledge and as a consequence to statistical literacy. There is no consensus at this time about the notion of statistical literacy in the relevant literature (Budgett, 2017). Gal (2002), referring to adults, describes statistical literacy as the "ability to interpret and critically evaluate" (p. 2) statistical information, as well as their ability to "discuss or communicate their reactions" (p. 3) to statistical information. He takes into account the impact that statistical literacy has for the effective citizenship since citizens are overwhelmed with statistics in modern societies. Gal divides statistical literacy into two components, a knowledge component and a dispositional one. For the knowledge component general literacy, mathematical skills and the ability to interpret graphs and tables are required. The dispositional component refers to the critical stance that adults should have towards statistical information presented to them, as coupled with certain attitudes and beliefs that would help adults to support their actions.

According to Watson (2006), graph construction and interpretation constitute a crucial part of statistical literacy. For the purpose of our research we focused on the definition of statistical literacy that concerns the "consumers" (Gal, 2002, p. 3), in other words, on statistics and the way that statistical literacy is expressed through the interpretation of graphs by users or readers. We focused on graphs that originate from media sources and may be misleading.

Graph comprehension literature review

The research about adults' graph comprehension is focused on in-service/pre-service teachers (Gonzalez, Espinel & Ainley, 2011) or students of vocational education (e.g. Bakker & Akkerman, 2014). Moreover, in national surveys aimed to adults, like PIAAC (Programme for the International Assessment of Adult Competencies, OECD, 2012) or ALL (Adult Literacy and Lifeskills Survey) there are tasks related with graph comprehension. However, we did not locate many studies about adults' graph comprehension in settings similar to a Second Chance School. Specifically, for ABE programs there is the study of Conti and Carvalho (2014), who investigated the teaching and learning of statistics in adult education mathematics classes. The researchers designed and implemented a project that was carried out with grade 7 students, aged from 16 to 43, in a public state elementary school in Brazil. Throughout this project some of the students constructed statistical graphs while most of them managed to establish an initial level of statistical literacy.

Monteiro and Ainley (2006; 2007) used media graphs as an assessment tool for the graph comprehension of pre-service teachers. These researchers concluded that for the interpretation of graphs not only a certain level of statistical knowledge was needed but also a kind of 'critical sense', especially given that their participants relied on their personal opinions and dispositions for their interpretations. Respectively, Queiroz et al. (2015) investigated the way that students with different academic backgrounds interpreted media graphs. These researchers found that the students mostly expressed their feelings and their opinions rather than making an objective analysis based on statistical knowledge.

Methodology

One of the main public institutions related to Adults' Basic Education programs in Greece is the Second Chance School (SCS). Its aim is to combat the social exclusion of adults who have not completed the compulsory secondary education and do not have the appropriate qualifications and skills to adapt to modern vocational requirements. SCSs are considered to be innovative, since they operate without pre-specified curricula, implement new teaching and evaluation methods and offer counselling to students (Efstathiou, 2009). For the Greek educational system, being conservative and rather rigid, the instruction and training in SCSs constitute an exceptional novelty (Koutrouba et. al., 2011). The duration of the studies in a Second Chance School is two academic years. The weekly programme consists of 25 teaching hours and the courses take place during the evening of all weekdays. Mathematics is taught for three hours per week in both cycles (grades) A and B. The main goal of mathematics teaching is the development of the students' numeracy and consequently their statistical literacy.

Our study took place in May 2015 and we used the methodology of a teaching research experiment (Steffe & Thompson, 2000). In particular, we designed an educational approach in which the basic statistical notions served as the basis for the development of adult students' statistical literacy. Initially, we designed a 12-hour sequence of lessons in accordance with the general guidelines for the teaching of statistics in SCSs (Lemonidis & Maravelakis, 2013). Our lessons contained: (1) data collection, data interpretation and organization, (2) reading and interpretation of basic data representations, (3) data description with statistical terminology, and (4) evaluation of arguments based on misleading graphs or incorrect statistical information. In this paper, we focus only to the lesson that concerned the graph comprehension.

For the purpose of this lesson, with a duration of two teaching hours (40 minutes each), we designed a series of eight tasks that consisted of graphs and their interpretation. These tasks were either adapted from relevant studies (PIAAC, PISA) or constructed from scratch for the purposes of the study. We based the task design on the following principles: (a) to include graphs within context, that show data from real-world situations and (b) to include misleading graphs since they are considered to be excellent cases for the students' motivation and assessment (Watson, 1997). Apart from their content, the tasks were formulated according to the learning goals and to a prediction of how the students' graph comprehension will evolve in the given contexts.

Although, according to the teaching experiment methodology an observer might be of great help to the teacher-researcher (Steffe & Thompson, 2000), in our case this was impossible due to the students' opposition. As a consequence, the mathematics teacher (first author) played the role of the researcher and tried as much as possible to share all the data with her fellow researcher. She was acquainted with the students' ways and means of operating since she had taught them for the previous six months. The teacher introduced new material with brief lectures at the beginning of the lesson, during which she posed questions for investigation and gave tasks to the students. For most of the course's duration, the students worked together with the teacher in order to answer specific questions included in the tasks. The students discussed statistical concepts, made conjectures, discussed the validity of specific arguments and applied the newly acquired knowledge to the next task. The teacher provided guidance, but she tried to interfere as little as possible and to promote with constant questions the students' active participation. The teaching episodes were audio taped and transcribed. Since the teaching was implemented to four different classes we had the opportunity to continuously discuss on the students' learning processes and on the role of the teaching materials we had constructed. This gave us the opportunity to make changes when it was needed and to revise some of the tasks or the related questions.

For the content analysis of the transcribed episodes, we used the levels of graph comprehension (Friel et. al., 2001; Shaughnessy, 2007) and the notion of critical sense (Monteiro & Ainley, 2007) as subcategories of graph sense. According to Friel et al. (2001) and to the additions made by Shaughnessy (2007), graph comprehension evolves through three ascending levels:

1. Reading the data: extraction of elementary information, recognizing components of graphs and detecting arithmetical information on graphs.
2. Reading between the data: understanding relationships among tables, graphs, and data, making sense of a graph, but avoiding personalization and maintaining an objective stance while talking about the graphs. Also, evaluating the graph for its constructive characteristics and detecting if it is misleading.
3. Reading beyond the data: making inferences from the graph in order to interpret the data, e.g., to compare and contrast data sets, to make a prediction about an unknown case, to generalize to a population, or to identify a trend. Recognizing appropriate graphs for a given data set and its context.

For the purpose of our analysis, critical sense refers to the act of mobilization (Monteiro & Ainley, 2007, p. 16) of diverse kinds of knowledge and experience during the act of graph interpretation. These researchers based their research on the levels of graph comprehension as proposed by Friel et al. (2001). In our study, we considered the critical sense and the graph comprehension levels as interrelated subcategories of graph sense. Graph sense refers to the general ability to read and deeply understand already constructed graphs found in the media (Friel et al., 2001).

Participants

In our study, 47 adult students aged from 20 to 62 took part, in four different classes with 10 to 14 students each. They all had a primary school leaving certificate and they attended the first year of a SCS (lower secondary) in a small town, with mainly rural population, in North-West Greece. The mathematical skill levels of these students varied from basic elementary level through secondary level, since some of them had completed the primary school while others had attended the first class of the gymnasium (lower secondary education). Most of these people were unemployed or unskilled workers. The following table includes the demographic data of the participants.

Table 1.

Demographic data of the participants.

	N	% of total		N	% of total		N	% of total		N	% of total
Gender			Age			Nationality			Occupational status		
Male	28	60%	[20,28)	3	6%	Greek	44	94%	Unemployed	25	53%
Female	19	40%	[28,36)	10	21%	Albanian	3	6%	Employees	22	47%
			[36,44)	20	43%						
			[44,52)	11	24%						
			[52,60)	2	4%						
			[60,68)	1	2%						

Results

We have chosen to refer to specific tasks due to space limitations. One of the tasks was about a bar-graph (translated to Greek) with a truncated scale which is given below. This task was based on a graph taken from the internet and we constructed the question.

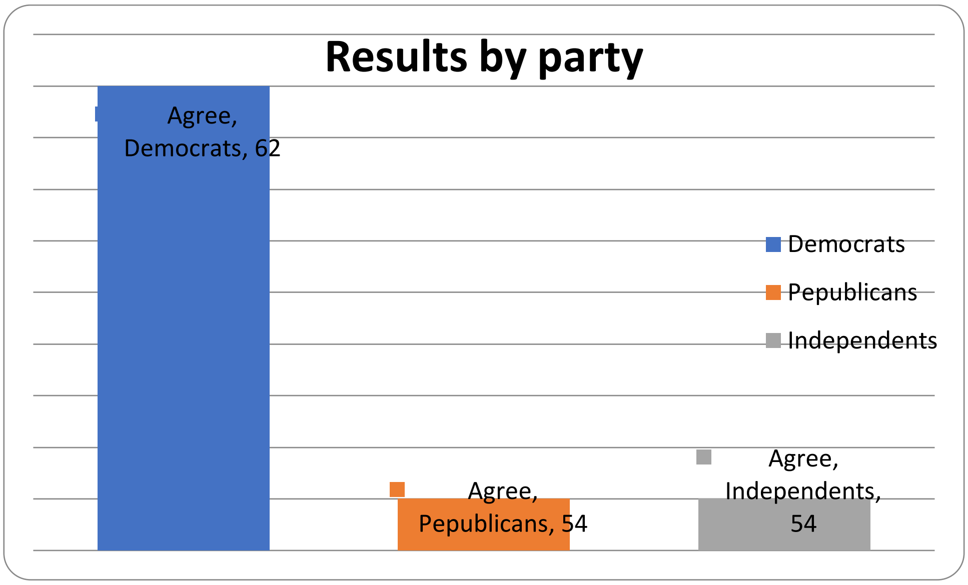

Figure 1. Third task. (adapted from Media Matters, 2005)

Question – Third task: In the United States, in 2005, CNN conducted a poll to test whether the voters for each party were in agreement with the court's decision about the Terry Schiavo's case and the next bar-graph was published. The source of the data was interviews conducted by telephone in March 18-20, 2005, with 909 adults in the United States. What is your conclusion based on this graph?

The first exchange comes from a class where the students discussed about the bar-graph and its accuracy. All adults' names appearing in the transcripts are pseudonyms. John responded negatively to the question posed by another student about the graph's correctness. He based his answer to the sum of the numbers that exceeds 100. He confused the bar-graph with the pie-graph where the sum of the sections must be equal to 100%. Helen asked about the 170 which is a number that the students mentioned before. Sophie answered to her by stating that 170 people say that they agree. She came to this conclusion by adding the numbers of the graph since 62+54+54=170.

John: No, it's more than 100.

Teacher: We have asked 909.

Helen: No, from 909 people, where does refer the 170?

Gregory: Maybe the percentage of the people asked is small?

Sophie: 170 say that they agree.

Gregory: Maybe the percentage of the people asked is small and we can't draw good conclusions?

Based on the above transcript we could say that the students' graph comprehension corresponds to the first level of reading the data since they read literally the graph focusing only to the given numbers. They extracted data directly from the graph and they tried to answer by relying only on the data shown in it.

In the second class during the same lesson the students interpreted the graph by observing its characteristics (bars) and the numbers represented by the bars. When Harry stated that we have 10 he referred to the 10 lines that he saw on the graph. In this way George understood the range of the numbers that are represented with the vertical axis. He realized that the wrong impression of this graph depends on the fact that the vertical axis' numbering does not start from 0 but from 53. George concluded that if the numbering was correct the bars' length would be different and the bar of 62 wouldn't look so much bigger than the bars of 54.

> George and Harry: (they discuss) In fact, it isn't true.
>
> Teacher: What do you mean?
>
> Harry: Because in fact we have 10…yes 10…
>
> George: Yes 10 lines. In fact if we notice it…I believe if there weren't any numbers …if we had began from 0 in order to go up it shows much bigger than 62. 54 has nothing to do with 62.

Another student (Eva), during the same discussion, trying to understand what her classmates were saying she confused the numbers on the bars with percentages. This was a problem for most of the students since they assumed that the numbers on the graphs referred to percentages. This was due to the fact that the students were not experienced graph readers; actually, this was their first attempt to read graphs after two lessons on the construction and the properties of basic graphs (bar-graphs, pie-graphs and line-graphs). It is obvious that the students of this particular class evaluated the graph's accuracy by noticing that the vertical axis is truncated. Thus, their graph comprehension corresponds to the second level of reading between the data since they detected the misleading effect:

> Eva: This starts from the middle, the 53, if it started from 0 wouldn't the percentage be bigger? Or not?
>
> Harry: No it wouldn't. The graph would be just bigger.
>
> George: By looking at the graph, what we can imagine…. That the first bar looks much bigger than 54…The difference is not so…They should be bigger (They talk simultaneously)

In the third class during the same lesson a student immediately found the inconsistency between the numbers and the bars. Joanna connected the numbers with the bars by comparing the bars' length and the difference among the numbers. She was able to respond at the second level of graph comprehension, reading between the data as it is evident in the next transcript.

> Teacher: (She reads the task). What can we conclude based on this graph?
>
> Joanna: Hold on a second… First of all, why the 54 is so down and the 62 is so up? It isn't correct; if it was reasonable then close to the 62 should have been the 54 and the other 54 of the independent.

Then the teacher asked the students to propose ways of reconstructing the bar-graph in order to correct its misleading effect. Joanna proposed a different scale in order to have a more accurate graph. In her answer it becomes obvious that she can understand the effect that the correct choice of scale has on the construction of the graph. Additionally, Joanna proposed that the numbering in the vertical axis should start from 0.

> Teacher: How would you make it in order to be correct?
>
> Ken: Without numbers.

Joanna: If you ascend 5 to 5 or 10 to 10 (she refers to the scale) it is impossible to have 54. This bar is too high (the one of 62), actually 62 is only 8 (units) more than 54. If we used 10 to 10 then 62 would be close to 54.

Teacher: So, you propose by ten…

Joanna: Yes, 10, 20, 30 and so on. This is what I mean.

Teacher: Yes, but where would you start from?

Joanna: From 0.

In this class during the same lesson the students had to solve the next task.

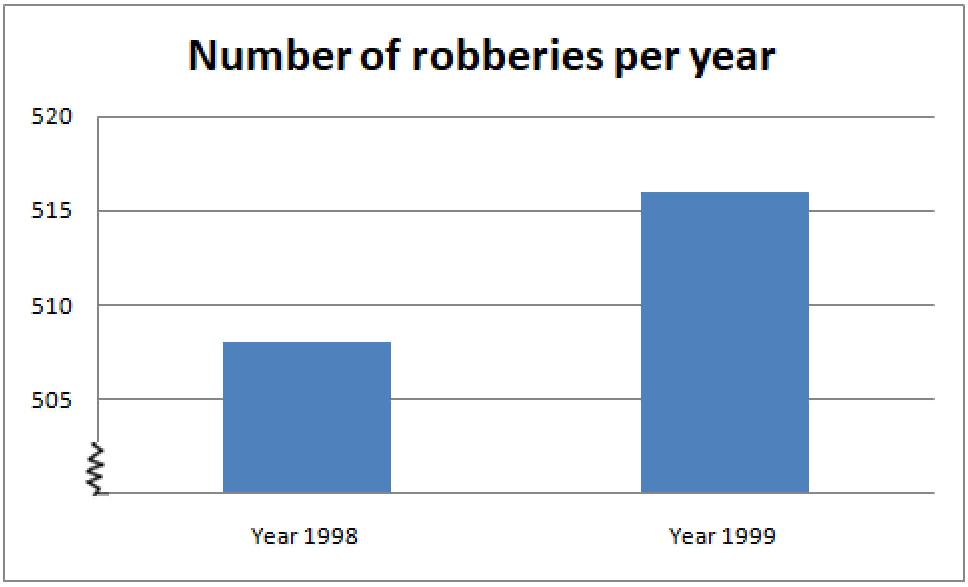

Figure 2. Fifth Task. (OECD, 2009)

Question-Fifth task: A TV reporter showed the above graph and said:
"The graph shows that there is a huge increase in the number of robberies from 1998 to 1999."
Do you consider the reporter's statement to be a reasonable interpretation of the graph? Give an explanation to support your answer.

Subsection 1 in section 1, using heading 2

In this part you type the text for subsection 1 within section 1 with ALMIJ body text.
Although Joanna responded correctly to the third task, which was familiar to her, she could not respond to this task which was familiar to all students. The students referred only to the numbers and they did not justify their answers. Joanna referred only to the relation between the bars and she did not connect their length with the numbers. Instead she focused on the numbers and confused them with percentages. When she could not justify her answer, she was confined to express her personal view about the graph.

Joanna: No

Steven, Ken: No.

Teacher: You have to justify your answers.

Joanna: It was 505 and goes to 520, how can we count its percentage?

Teacher: You can't since you don't know the whole.

Joanna: So, what? How would I answer?

Teacher: He said that the increase was great.

Steven: Is the difference big?

Joanna: It is two, it is two times.

Leo: No, it isn't correct.

Joanna: We don't like it.

Another student, Leo, who was silent from the beginning of the lesson, noticed the inconsistency between the numbers and the bar's length. He concluded that the graph is not correct since the second bar is twice the first one while the relevant numbers do not follow the same pattern. Leo managed to read between the data and his comments assisted the other students to express their opinions. Joanna concluded that this graph was used by someone to deceive the readers and Robert expressed a reasonable conclusion about it.

Leo: Because here it is 505, after it is 510 and then the double of it (he refers to the bars) goes to 520.

Teacher: So?

Leo: So, it can't be correct.

Teacher: Do you say that if I look at the numbers the robberies are double?

Leo: No, the numbers aren't double.

Joanna: So, they are trying to deceive us.

Teacher: Robert do you agree?

Robert: I believe the graph is wrong since the number of robberies isn't double as it looks on the graph.

The next exchanges are about the sixth task which contained a line-graph and was provided during the second hour of the same lesson.

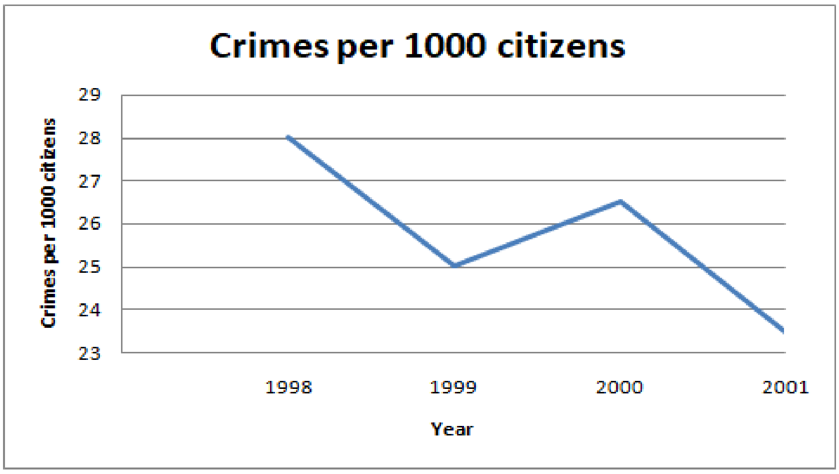

Figure 3. Sixth Task. (adapted from Harper, 2004)

Question-Sixth task: In a local newspaper in 2001 we found the above graph about crime rate in the region from 1998 to 2001. The article concludes that crime rate had been reduced to a great extent. Do you agree with that? Justify your answer.

In the fourth class during the second hour of this lesson Maria based her answer on her personal views. She expressed her opposition to the conclusion that accompanied the graph. It seemed that she did not even read the graph, but she merely expressed her disapproval. At the same, time Paul stated that he agreed with the graph since he read literally the graph focusing only to the given numbers.

Teacher: Let's go to the sixth task now (she reads it). The article concluded that criminality had declined to a great extent. Do you agree with this?

Maria: Nonsense. No.

Teacher: Do you agree with this claim? Justify your answer.

Maria: No. As the years go by, criminality becomes greater, not less.

Paul: I agree with the graph, because the graph is correct. I see that in 1998 we had 28 crimes, in 1999 we had 25, in 2000 we had 27 and in 2001 we had 24 hence... I agree.

Afterwards the teacher tried to urge the students to notice the graphs' numerical information in order to understand the inconsistencies. Yanni with his question referred to the effect of the previous tasks. Maria concluded that it should have started from 0 and the scale should have been 1. At the end Yanni concluded that the reduction is very small.

Teacher: Was the decline so great?

Paul: As it seems here, it is not a big reduction but…

Yianni: Isn't it the same again?

Paul: So isn't the graphic representation right?

Teacher: Why is it not right?

Maria: Because it should have started from 0 and maybe go one by one here.

Teacher: Maybe one. If I understood what you said, in 98 was 28 and in 2001 was 24, what is the difference of 28 in 24, how much do we have?

Yanni: 4

Teacher: 4 out of 1000 inhabitants, is this a big reduction?

Yanni: It's nothing.

In the other classes most students interpreted this graph correctly and evaluated its accuracy by using their knowledge from the previous tasks. Some of them – coming from the first class – managed to propose its reconstruction, by using their knowledge about graphs. Eva proposed to change the line-graph to a bar-graph and Helen imputed the wrong effect of the graph to the choice of the scale.

Eva: If we used bars wouldn't it look better?

Theo: It looks that the decrease was huge.

Helen: But the difference isn't as huge at it looks like because the scale is 1. If the scale was 10 it would be…

Eva: If we used bars from 28 to 24…Wouldn't it be the same?

Teacher: If I construct it again and start from 0 what scale should I use?

Helen: By 5.

> Teacher: (Constructs it in the blackboard according to the students' suggestions). So, now, how it does it look?
>
> Eva: Now the decline doesn't look so big. While in the first graph (task) it looks like the decline was very big. Now it looks okay….

We may say that these students partially demonstrated the highest level of graph comprehension, reading beyond the data, since they were able to connect the same data with another graph in an attempt to produce a more accurate presentation of them in relation with the graph's context.

Conclusions – Discussion

Numerical activities take place every day since people have to confront numerate situations all the time (Diez-Palomar, 2011). Additionally, numeracy is highly connected to statistical literacy; at least to the extent that statistical literacy refers to the abilities that adults as 'consumers' of statistical data should have in order to be active citizens. One of the situations that statistical literacy is needed is graph interpretation. In light of these considerations we designed our research. Our underlying goal was not only to assess the way that adult students interpret graphs in context or media graphs but also to enrich their experiences by providing them with statistical notions which were new for them. These notions were new for our students since they were inexperienced readers of graphs. Our intention was to encourage our students to approach every task as a part of their everyday life. In this way they would appreciate statistics and the impact it has for their effective participation in society.

Concerning the way that our students interpreted the graphs, most of them were able to read the graphs and to extract numerical information from these. They managed to use their previous knowledge to solve the tasks and they realised that a graph is a data representation that must meet certain requirements. Therefore, they could read these data. The students demonstrated to some extent the ability to critically evaluate graphs and to identify the deliberate use of misleading graphs that results to wrong interpretations. Not all of them were able to read between the data. With respect to the third level of graph comprehension – reading beyond the data – very few students generalized from the sample to the population based on specific graphs or were able to reach a conclusion.

It is noteworthy that the students' personal opinions occasionally overwhelmed their knowledge of the graphs; we may say that in these cases they did not operate well because they acted based on a drive provided by their emotions (Buxton, 1991) and they did not manage to overcome their prejudices against their statistical knowledge of graph interpretation. The context of the graph played a significant role in the students' interpretations; they reached some conclusions without considering the meaningfulness of their answers. Thus, the graphs' realistic context in our study had lead to "unexpected responses and outcomes" (Dalby, 2015, p. 88). The students' critical sense was not so developed since a balance between their knowledge, beliefs and experience in interpreting the graphs was not achieved.

In his seminal paper on the role of visual representations, Arcavi (2003) mentions a phrase attributed to Goethe: "We don't know what we see, we see what we know" (p. 230) to refer to the cases in which students do not see what teachers or researchers see. Especially, the second part of this phrase – "We see what we know" – may refer to all those adults who have to interpret different forms of visual data, including statistical graphs or media graphs without having a statistical background. Some of our students have managed to overcome their prejudices, while others not. Thus, we believe that our study has provided some evidence on how the endeavour of providing a statistical background might look like.

Further research is needed with larger groups of adults, adults with different levels of knowledge and possibly a bigger variety of contexts. This could provide support for the work of Monteiro & Ainley (2007), since the different features of reading contexts has helped us to highlight that the interpretation of graphs is related with school and out-of school knowledge. The teaching of correctly reading statistical graphs seems to be of crucial importance in a world where the average adult has to confront with graphs in almost every strand of his daily life. This is especially true for the adult learners who return to their studies carrying their own experiences from in and out of school, and at the same time they need to confront with all their prejudices on their attempt to interpret an ever-changing world.

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