USING UNITED NATIONS DATA IN THE TRAINING OF TEACHERS TO TEACH STATISTICS

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In this paper we describe a workshop aimed at prospective secondary and high school teachers in Spain, which was based on social data taken from the United Nations web server. These data were used to evaluate and increase the teachers' knowledge to teach statistics in secondary and high school. Visualization and analysis of the data was based on simple tools, including spreadsheets, Internet applets, as well as a variety of multivariate display tools available in the United Nations public Data Explorer. Contexts such as life expectancy and gender inequality helped to increase the interest in social data and statistical data analysis in the workshop participants.

INTRODUCTION

There is a consensus today that students need to understand statistics to make adequate decisions when confronted with uncertainty. Consequently, statistical reasoning and its role in decision making and professional work is being emphasized in curricular guidelines around the world, including the Spanish curriculum for secondary and high school level (CCSSI, 2010; Franklin et al., 2007; MECD, 2015).

These curricular guidelines suggest that teachers should promote the students' work with statistical projects and real data, the use of technology and interpretative activities. The collection of data is quickly growing both in the amount of data and in relation to the range of topics on which data is collected. Accessing data has become much simpler, and tools for exploring, manipulating and representing data have multiplied, including freeware (Nicholson, Ridgway, & McCusker, 2013).

Furthermore, national statistics offices and international agencies such as the United Nations (UN) or the World Health Organisation (WHO) make their statistical studies available on the Internet. A recommendation is to take into consideration the facilities provided by technology and the open data movement where many organisations make high quality data available to citizens in general and to students and teachers in particular (Ridgway, 2015).

The aim is to develop the students' statistical literacy, that permits them to understand, interpret, and critically evaluate statistical information or arguments conveyed by the media and other sources (Gal, 2002). In Wallman's words:

> The ability to understand and critically evaluate statistical results that permeate daily life, coupled with the ability to appreciate the contributions that statistical thinking can make in public and private, professional and personal decisions (Wallman, 1993, p.1).

Consequently, to be statistically literate, people need a basic understanding of statistical terms and symbols; being able to read statistical graphs understanding the basic logic of statistics; and understanding and critically evaluating statistical results that appear in everyday life.

The aim of this paper is to describe a workshop directed to enrich teachers' statistical literacy and their competence to develop statistical literacy in their students. The workshop was based on rich and authentic social data downloaded from the United Nations Human Development Reports web server (http://hdr.undp.org/en/data), which can be used by teachers with their own students. The variables used are relevant to the understanding of social topics and civic phenomena and increase the motivation of both teachers and students. In particular, we used data related to life expectancy and gender inequality to organise formative activities aimed at simultaneously increasing the different components of prospective teachers' knowledge related to teaching statistics.

Below we first develop some ideas about the components of teachers' knowledge, then describe the educational context and the workshop design and present some results of evaluation

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the workshop in a sample of 65 prospective teachers. We finish with the discussion of some implications for the education of teachers.

TEACHERS KNOWLEDGE

The success of statistical curricula depends on the adequate preparation of teachers. A wide research is focused in the analysis of teacher's knowledge that includes both content and pedagogical content knowledge. As a consequence, there is agreement that the teacher education which should be reinforced in the different components of this knowledge. In this paper we will consider Mathematical Knowledge for Teaching (MKT; Hill, Ball, & Schilling, 2008), which includes the following components, all of which are relevant for the teaching of statistics, which is the content we are interested in:

a. *Common content knowledge* (CCK), according to Ball, Thames and Phelps (2008, p. 399) is "the mathematical knowledge and skill used in settings other than teaching." In our interpretation, this type of knowledge includes basic skills and general knowledge about the topics that are to be taught to students.
b. *Advanced knowledge of content:* a wider knowledge than that to be taught and that helps the teacher to relate the content to other topics and areas; ACK). First grade teachers, for example, may need to know how the mathematics they teach is related to the mathematics students will learn in third grade to be able to set the mathematical foundation for what will come later.
c. *Specialized knowledge of content* (SCK)*:* a type of knowledge specific of teachers which is essential for teaching and is not shared with other professionals; for example, the ability to propose different strategies to solve a specific problem or to explain its solution to students as well as the capacity to identify the statistical content in a teaching activity;
d. *Knowledge of content and students*: the teacher should be familiar with how students work and think about statistics; predict their difficulties and strategies in solving the tasks, their beliefs and interests related to the topic;
e. *Knowledge of tools and ways to teach the content*: including didactic resources, textbooks, distribution of a topic over time, etc. ; and
f. *Knowledge of curriculum:* aims, contents, relationships with other areas, etc.

Since the time to prepare these teachers is scarce, Godino, Ortiz, Roa, & Wilhelmi (2011) suggested the use of a formative cycle where prospective teachers first work with a statistical project based on real data, so that they enrich their statistical common and advanced knowledge and reasoning, as well as their experience with teaching statistics by working through projects and using technology. Secondly, teachers perform a didactic analysis of the project, in order to reinforce the different components of their pedagogical content knowledge. Below, we summarise our experience in a workshop aimed at prospective secondary and high school teachers, which is based on this philosophy.

CONTEXT AND SAMPLE

The context where the workshop has been developed in the past three years is a Masters' course in Mathematics Education, which is compulsory in Spain for those who want to apply for a teaching position in secondary or high school. Prospective teachers have to take 60 credits (each credit is about 10 teaching hours), 8 of which can be selected from any topic. Twelve credits consist of general pedagogy and didactics, 6 credits include complements of mathematics (e.g. history) and only 18 credits are devoted to mathematics education. The prospective teachers also do practical work in schools (for about two months; 10 credits) and prepare a Master's thesis (6 credits) related to different aspects of teaching mathematics (e.g. analysis of curricular materials, assessment of students' learning or innovative experiences in the classroom). There is no specific component of statistics education, although part of the participants prepare a Master' thesis in statistics education.

The sample of prospective teachers taking the course (and taking part in the workshop) were respectively 23 (in 2013), 42 (in 2014) and 53 (in 2015) participants. All these prospective teachers had previously finished a Bachelor in mathematics or statistics (about 60% participants) or in Sciences/Engineering/Architecture. Consequently, their mathematical knowledge was advanced;

however their statistical preparation was in general reduced to one statistics course with theoretical orientation (apart from students with a Bachelor in statistics). None of the students had previously studied statistics education contents and their only contact with statistics education was through the workshop.

WORKSHOP DESIGN

The workshop design followed the formative cycle proposed by Godino et al. (2011) and consisted of four 2- hour long sessions (8 teaching hours in total), where participants had access to computers and Internet. In the first and second sessions the participants were given the statistical project: "Life expectancy in different countries" to investigate the relationship between the life expectancy in different countries and different international indicators of human development (in 2013 and 2014); in 2015 we used the project "Factors that determine gender inequality". Participants were also requested to do some personal work out of the classroom.

Participants were also provided with an Excel file with the data set containing data from 9 variables from about 200 countries (the Spanish curriculum suggests the use of Excel with the students). In order to cover all the statistical content in the curriculum, the prospective teachers were asked to interpret graphs and statistics, compare distributions (e.g. percentages of women and men at work in the different countries), estimate and explain correlation (of life expectancy and Gender Inequality rank with different indicators) and find a regression that fits the data (linear and non-linear models were used). Although the Spanish curriculum does not include elements of multivariate regression (or multivariate data analysis in general), some elementary activities of multivariate data visualization using tools available on the United Nation web server were also included in the workshop, in order to reinforce the teachers' advanced statistical knowledge. As an optional activity (out of the classroom activity), participants were asked to choose and download other variables from the UN server, analyse the new data and prepare a report with their conclusions.

In the third and fourth sessions a didactical analysis was carried out, which included the following analyses:

a. Identification of the teaching goals in the activities, identification of the content needed by the student to solve the tasks and locating this content in the curricular guidelines for high school (aimed at increasing the participants' specialized and curricular knowledge),
b. Predicting the students' potential difficulties and assessing the affective components in the activity; identifying common misinterpretations of statistical concepts, such as median or correlation (knowledge of statistics and students). The prospective teachers used their previous experience with the project to identify the difficult points in each activity.
c. Discussing the particular challenges of teaching statistics through projects and real data (using the particular example of the UN data); evaluating the materials, data used in the activity and technology used in the project; suggesting other materials and software, or Internet applets that could be used to support the students' learning; suggesting other ways to conduct the lesson (all these activities contributed to improving the participants´ knowledge of teaching statistics).
d. Practising elementary statistics analysis using Excel to analyse the UN data which contributed to participants' advanced knowledge of statistics.
e. Reading some papers on the effect of non-controlled variables on correlation; the difference between correlation, partial and multiple correlation and the Simpson paradox were also suggested as out of classroom activities to reinforce the participants' advanced knowledge of statistics.

To follow we restrict the description to the statistical data analysis activities carried out in the first two sessions in the years 2013 and 2014; similar activities were carried out with the Gender inequality project in 2015. Some details of the performance of the activities related to correlation in the two first years were presented in Batanero, Gea, Díaz and Cañadas (2014) and details of the solution of the activities are included in Batanero and Borovcnik (2016).

DATA AND CRITERIA FOR SELECTION

To start the project, the lecturer provided the prospective teachers with an Excel file with the following statistical variables (the definition of these variables are reproduced from the UN web site):

- *Life expectancy at birth (years)*: Number of years a new-born could expect to live if prevailing patterns of age-specific mortality rates at the time of birth stay the same throughout the infant's life.
- *Human Development Index (HDI) value*: A composite index measuring average achievement in three basic dimensions of human development - a long and healthy life, knowledge and a decent standard of living.
- *GDP per capita (2005)*: Sum of gross value added by all resident producers in the economy plus any product taxes and minus any subsidies not included in the value of the products, expressed in international dollars using purchasing power parity rates and divided by total population during the same period.
- *Adolescent fertility rate*: Number of births of women aged 15-19 per 1,000 women of these ages.
- *Under-five mortality*: Probability of child mortality between birth and exactly age 5, expressed per 1,000 live births.
- *Expenditure on public health*: Current spending from government (central and local) budgets, external borrowings and grants (including donations from international agencies and nongovernmental organizations), and social (or compulsory) health insurance funds, expressed as a percentage of GDP.
- *HDI education index*: takes into account distribution of years of schooling.
- *Population, total* both sexes (in thousands).
- *Population, urban*: percentage of total population living in areas classified as urban according to the criteria used by each area or country.

The aim of using real data was leading the prospective teachers to reasoning with evidence and multivariate data, and increasing their statistical literacy to be informed citizens (Ridgway, Nicholson, & McCusker, 2006). In addition to univariate and bivariate analysis (as required in the Spanish school curricula) teachers were asked to perform some multivariate visualizations using tools available on the United Nation web server which, according to Ridgway (2015), provide a rich resource to discuss the strengths and weaknesses of different data representations with students.

STATISTICAL ACTIVITIES IN THE WORKSHOP

The full project included the following statistical activities, for which each of the participants had to analyse the data and provide their solution in a written form. All these activities contribute to the empowering of the teacher's content knowledge (interpreted in the sense of Ball, Thames, & Phelps, 2008). Below we briefly describe the activities.

1. *Introductory activities:*

Participants were asked to describe the meaning of the different variables, find the way they are collected, explain the difference between elementary and aggregate data (average for a country), and assess the use of these variables in public policy and management. Secondly they became familiar with the distribution of life expectancy through different graphical representations and statistical summaries. For example, they discussed the composition and meaning of GDP and HDI and they looked for news in the daily press related to life expectancy or adolescent fertility rate. They also compared the rank of Spain (in relation to the whole date set) for each of the variables. These introductory activities were important for participants who were thus able to understand the data within its context and connect the data set to the problem under research. A second goal was assuring the participants' interest in the study of life expectation (Hall, 2011).

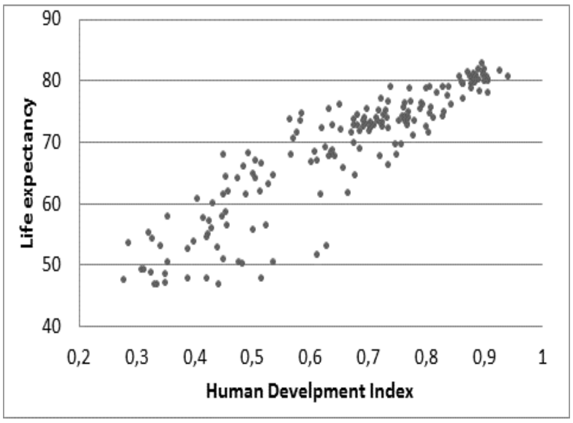
2. *Comparing distributions:*

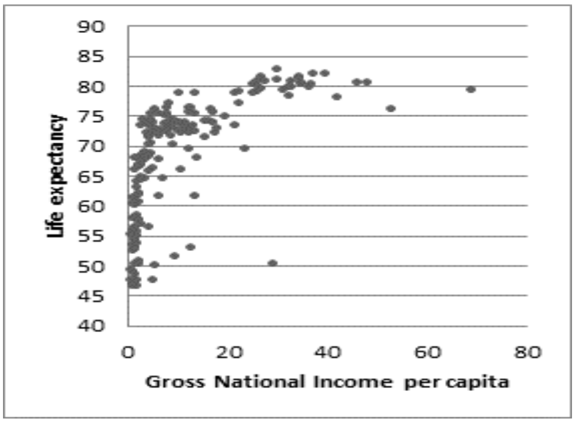
In the current emphasis towards the early introduction of informal approaches to inference (e.g., Makar, Bakker, & Ben-Zvi, 2011) a privileged context is the comparison of two distributions. We intended to motivate the workshop participants towards this task, using different graphs (histograms, box plot, and cumulative diagrams) to compare life expectancy and mean number of years in school in men and women. They were asked to compare these graphs and some statistical summaries, and to describe their conclusions about the main differences in the distribution in terms of centres and spread. In general, participants interpreted correctly the histogram, cumulative frequency plot and box plot; however, about 30% of them made some mistakes in interpreting the standard deviation or the percentiles. An additional task was finding countries with atypical behaviour in these variables and explaining the observed differences in terms of other variables in the data set.

3. *Interpreting correlation:*

Correlation is a topic where both students and teachers present many misconceptions (Engel, & Sedlmeier, 2011). In Figure 1 we present the activities designed to provide a meaningful introduction to this topic.

Variables influencing Life expectation. In the following graphs life expectancy is displayed as a function of different variables[1]





Activities:

1. Assign each graph a score according your perception of the strength of the relationship; 0 means there is no relationship and 1 is the maximum strength.
2. In each graph assign a sign (+ or -) depending on whether you think the relationship is direct o inverse.
3. Order the variables according to your perception of their better utility to predict the value of life expectancy
4. Do you think it is possible to use a mathematical model (function) to estimate the value of the life expectancy, given the value of some of these variables? What type of function? Why? Describe the meaning of the model parameters.

[1]Similar scatter plots were provided for all the different independent variables in the file

Figure 1. Questionnaire given to participants

Firstly (in activity 1), participants were asked to assign a value (between 0 and 1) to measure the strength of association from different scatter plots representing life expectancy in terms of each of the other variables. These scatter plots included linear and nonlinear relationships, as well as direct and inverse association and independence. Students were subsequently asked (activity 2) to assign a sign to describe the type of correlation (direct or inverse) when possible (we also included examples of independent variables and nonlinear associations).

A summary of results in these two activities is presented in Table 1, where we see that participants were accurate in estimating correlation, although there was some influence of participant' previous theories (urban population) and of negative correlations (adolescent fertility rate; under five mortality) on the accuracy of estimates. The sign of correlation was correctly perceived in most variables, although many participants assigned a positive sign to the case of independence (total population).

Table 1. Mean value of estimated absolute value of correlation, and percentage of students providing correct responses to sign of correlation

Variable	True correlation value r in the data	Mean of estimated abs. value of correlation	% correct assignment of sign
Human Dev. Index	0.91	0.90	100
GDP per capita	0.62	0.72	100
Fertility rate	-0.73	0.47	100
Under five mortality	-0.92	0.80	100
Expenditure on health	0.38	0.22	61
HDI educational index	0.78	0.65	100
Population, total	0	0.01	21.7
Population urban	0.61	0.36	100

In activity 3 the participants should order the variables according to their utility to predict life expectancy; this order is given by the determination coefficient *D,* which measures the percentage of the total variance of life expectancy which is explained by the regression model (or similarly the goodness of fit). In case of linear association*, D* is equal to the square correlation coefficient r^2. Intuitively the power of prediction may be evaluated by examining the spread in the scatter plot. The larger is the spread of dots in relation to the bivariate distribution tendency, the smaller is the power of prediction. In order to evaluate the participants' intuitions in relation to this point, we computed the determination *D* for all the scatter plots, taking the most suitable model in case of nonlinear association.

In Table 2 we present the true order the prediction for each variable (that was determined by comparing the respective true determination coefficients *D*) and the mean value of orders assigned by the participants. Although the order in the power of prediction was harder to be recognized by part of participants, most of them ordered correctly the variables or provided a rank close to the right response.

Table 2. Mean order assigned by participants to the independent variables according their power of prediction for life expectancy

Variable	True order of prediction measured by *D*	Mean order assigned by participants
Human Dev. Index	2	1.6
GDP per capita	5	4.8
Fertility rate	4	4
Child mortality	1	1.9
Exp. on health	7	5.4
HDI educ. index	3	3.3
Population, total	8	7.5
Population urban	6	6.5

4. *Model fitting.*

For those variables that presented a strong association with life expectancy, the participants were asked to identify the type of model (mathematical function) that best fit the data (from observation of the scatter plot). The scatter plots included data with different models of fit (linear, logarithmic, polynomial, power and exponential models). Although it would be possible to transform the data of nonlinear models using appropriate transformations, the participants could work directly with Excel that provides regression analysis for a range of different functions they were familiar with and provides both the determination coefficient (denoted as R^2) and line of best fit in the given family of functions. Participants should use Excel to try different models and compare the determination coefficients in order to evaluate the percentage of variance explained by different possible models.

Consequently, when more than one model was possible, participants were asked to select a suitable model (that at the same time explains a reasonable amount of the response variable and was simple enough). Finally they had to interpret the meaning of the parameters in the model and compare the residuals in different models of fit.

In Figure 1 we reproduce an example where a student fitted an power model to describe the relationship of GDP (PIB per capita in Spanish) with under five mortality rate (Tasa de mortalidad de niños menores de 5 años in Spanish) using Excel. This regression line accounts for a 75.47% of variance in the bivariate data, which was considered reasonable by this student.

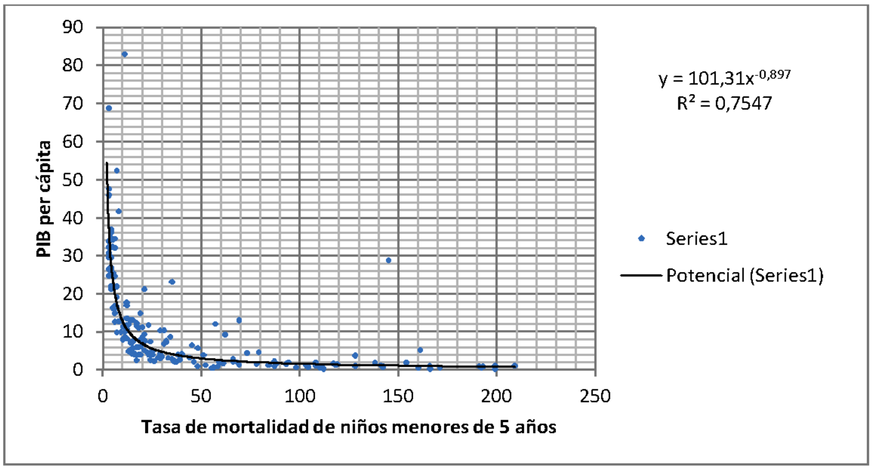


Figure 1. Fitting a non-linear model to the data

This activity was correctly performed by about 80% of the participants. No student tried to fit a model in case of perfect independence (Population, total). The accuracy in fitting an adequate model was smaller in those variables with linear relationship but smaller correlation.

5. *Multivariate visualization.*

As an optional out of classroom activity, the participants were asked to simultaneously display some variables, using the visualization tools offered by the UN Public data explorer (e.g. The bubble chart or different types of maps). These tools allow for a variety of visualisation possibilities, choosing a variety of complementary variables, selecting countries or regions, etc. This activity was aimed at making prospective teachers understand that their previous prediction of life expectancy could be improved when considering more than one explanatory variable. Participants were asked to analyse life expectancy in terms of three explanatory variables using the bubble chart, observing change with time and reporting changes over time in particular countries (for example: Spain). About 40% of prospective teachers completed these optional activities, in general in a correct way.

In Figure 2 we reproduce the graphs provided by one participant, who selected a new variable not included in the original file (expected years of schooling of children) as independent variable. The student downloaded the data for this new variable from the UN web server and displayed in the bubble chart life expectancy at birth (dependent variable) as function of expected years of schooling (x axis), population in the country (bubble size), and human development index (bubble colour). She changed the year (bottom of the graph) to produce four different graphs and analysed the changes produced in Spain (labelled in the graphs) over a long time period (from 1980 to 2012). Finally the student provided an interpretation of the changes observed in the bubble chart over time. Some comments of this student are reproduced below:

> We can see that both life expectancy and expected years of schooling rise in almost all countries since 1980 to 2012; so did the human development index. The darker bubbles correspond to countries with higher development index which also have larger life expectation and expected years of schooling. The bubble size represents the country population and we can see there is no influence on any of the other three variables.
> As regards Spain, the life expectancy increased from 73 years in 1980 to 80 years in 2012 and the expected years of schooling increased to almost 17 years. This means that now there is a higher percentage of population with secondary and university studies, probably because of the government support to higher education with grants and there are more (10) years of compulsory education.

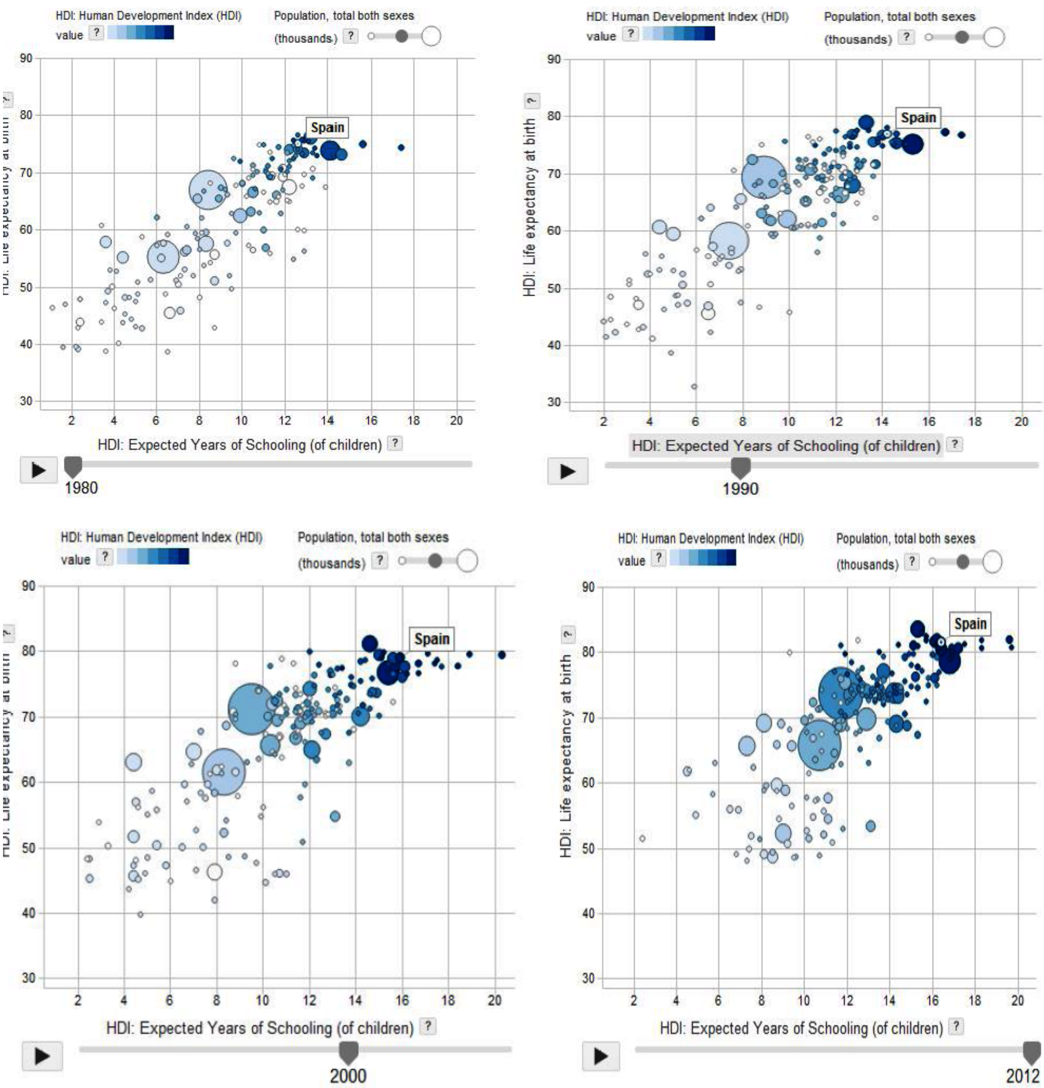


Figure 2. Multivariate graphs provided by one participant

EVALUATION OF THE EXPERIENCE

The current amount of data accessible on the Internet, on almost any topic that may interest students, helps to facilitate working with real data (see, e.g., Hall, 2011; Ridgway, 2015). In our experience, the use of social data proved to be successful in order to enrich different components of prospective teachers' knowledge with the different activities described in the previous sections.

These activities also increased the participants' interest towards statistics and its teaching and their willingness to learn more and be better prepared to teach statistics in secondary or high school with real data and technology, as well as to select their own works of research in topics of interest to them. Contexts such as life expectancy and gender inequality helped to increase the participants´ interest in social data, since they could investigate issues that are rarely dealt with in traditional problems in textbooks. For example, they gained a better understanding of different data types, the advantages and problems when working with aggregate data, perceived additional problems in managing missing or incomplete data, encountered data that were atypical in real contexts and discussed questions of reliability and validity of the investigated data.

The experience also helped these prospective teachers perceive the enormous work and collaboration needed among countries and institutions involved in collecting official statistics and the relevance of these statistics in planning, management and public policy. Consequently, the perception of the value of statistics increased as well as their willingness to make their own students conscious of this relevance.

The prospective teachers' solutions and responses to the different tasks are being analysed to discover the points where prospective teachers need further preparation. Our preliminary results suggest problems in interpreting aggregate data and their averages, in deciding which average is preferable to represent a particular variable or in interpreting the meaning of standard deviation. These are points that should be reinforced in future workshops directed at teachers. We hope this experience may help other lecturer involved in the training of teachers to teach statistics to continue research; for example, designing other similar workshops where real social data are used to increase the teacher's knowledge and their interest in teaching statistics.

Our experience was based on the use of spreadsheets (Excel), since it provides useful tools to study correlation and regression and it is recommended in the Spanish curricular guidelines (MECD, 2015). We also used tools provided by the United Nations website (Public Data Explorer); another possible research is to compare with the use of other available and appropriate tools for data analysis and visualization that permit students to engage with real data as described in Biehler, Ben-Zvi, Bakker and Makar (2013).

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