THE USE OF STATISTICS IN REAL AND SIMULATED INVESTIGATIONS PERFORMED BY UNDERGRADUATE HEALTH SCIENCES' STUDENTS

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In previous works, we evaluated the statistical reasoning ability acquired by health sciences' students carrying out their final undergraduate project. We found that these students achieved a good level of statistical literacy and reasoning in descriptive statistics. However, concerning inferential statistics the students did not reach a similar level. Statistics educators therefore claim for more effective ways to learn statistics such as project based investigations. These can be simulated, based on previously supplied data, or real, based on data collected by the students themselves. In this work, we intend to evaluate and compare the statistical reasoning and thinking ability acquired by health sciences' students when conducting both real and simulated investigations.

INTRODUCTION

In a world of data, statistics educators claim for more effective ways to learn statistics. According to Garfield's principles to learn statistics, students learn by:

a) Constructing knowledge;
b) Active involvement in learning activities;
c) To do well only what they practice doing (Garfield, 2007).

The project approach can lead to a better statistical education allowing students to supplement what they learn in class by doing statistics. In both real and simulated investigations, students can identify and analyze problems by means of statistics achieving an in-depth comprehension. Students can also learn from the data and make decisions under uncertainty by extracting vital information from the data. It requires pertinent synthesis and communicative abilities (Pimenta, 2006, 2009; Balderas, 2008; Nascimento, 2008).

Developing statistical literacy, reasoning and thinking is particularly pertinent in the field of the health sciences since we have great evidence of *statistical illiteracy* and statistical errors in the medical literature (Altman, 2002; Altman et al, 2002).

In real projects, students can carry out small investigations in which they design studies, collect data, analyze their results and prepare written reports and oral presentations. In simulated projects students do not collect the data but a database, and a description of possible problems is provided. In both types of approach, students are constructing knowledge, have active involvement in learning activities and they practice by doing statistics.

Nonetheless, to work with projects encounters a critical challenge to statistics educators: it is necessary to assess these projects in a systematic way. In working towards overcoming this challenge we developed a tool to assess statistical projects. In a previous work (Pimenta, 2006), we evaluated statistical reasoning ability acquired by health sciences' students in the course of their final undergraduate project based on real investigations. In this work, we intend to evaluate and compare the statistical reasoning and thinking ability acquired by health sciences' students, when conducting both real and simulated investigations.

METHODS

Participants

The original sample consisted of 348 students (73 male, 275 female; mean age +/- SD 23.17 +/- 2.07.37 years) attending the Escola Superior de Tecnologia da Saúde do Instituto Politécnico do Porto in Portugal. No significant statistical differences for gender and age were found between the two groups of participants. The students were enrolled in a compulsory

In C. Reading (Ed.), *Data and context in statistics education: Towards an evidence-based society. Proceedings of the Eighth International Conference on Teaching Statistics (ICOTS8, July, 2010), Ljubljana, Slovenia*. Voorburg, The Netherlands: International Statistical Institute. www.stat.auckland.ac.nz/~iase/publications.php

graduation project in their own field of specialization. A first group (n=223, 64.1%) developed a real investigation project and a second group (n=125, 35.9%) developed a simulated investigation project. The two groups of students were formed by assigning a real investigation to one class and a simulated investigation to another. In the real investigation group, students were given the opportunity to decide on their own projects, having to define the question and gather the necessary data on it. In the simulated investigation four different projects, consistent in terms of depth and difficulty, were previously defined and then randomly assigned to the students. In order to guarantee consistency and a similar level of statistical usage the criteria present in Table 1 were previously given to both groups of students.

Instrument

To assess statistical reasoning and thinking in a systematic way we developed a 24 items rubric that covered the entire statistical cycle of investigation. Rueckert (2008, p.2) defined rubric as an *assessment tool, usually used to measure outcomes, that cannot be easily captured by simpler standardized tests*. They usually take the form of a grid that includes a list of outcomes or criteria. The outcomes or criteria in our rubric were based on our previous studies developed according to the statistical literacy and reasoning constructs (Gal, 2002; Wild & Pfannkuch, 1999).

Concerning validity, the items were checked by a group of biostatistics teachers who demonstrated great agreement in using these items to evaluate statistical ability through project work. For the predictive validity we used the students' results in the biostatical course and the total score obtained in this rubric reaching a correlation of 0.74. Concerning reliability analysis, we found a Cronbach's α of 0.83 in the total sample, and 0.76 in the real investigation group, ascending to 0.89 in the simulated investigation group which demonstrated a high level of internal consistency. The rubric was also checked in order to determinate inter and intra observer reliability by using the total score by observer. This score was calculated by adding all variables that were involved in the rubric. The inter-rater reliability obtained was 0.92 and the intra-rater (before and after six months) reliability ascended to 0.98.

Procedure

The assessment tool was applied to the two different groups of projects after having been concluded. To evaluate the differences between the two groups, after normality checking by symmetry and kurtosis analyzis, we used the t test for independent samples.

RESULTS AND DISCUSSION

As we can see in table 1, students' projects are generally well rated which demonstrates a higher level of performance when compared with statistical examinations. Allowing students to develop a project in their own field provides them the opportunity to learn statistics by doing statistics. Simultaneously, they begin developing research skills which are identical to the ones applied to a statistics process.

No significant statistical differences were found between the two groups concerning: 1) the definition of the variables (dependent and independent); 2) the explanation on the method under which the sample was obtained; 3) the relevance of that sampling method; 4) the use and interpretation of the dispersion measures; 5) the adequacy of the statistical procedures to the problem and variables. As our previous studies demonstrated, health students achieved a good level of basic statistical literacy and reasoning apart from working with real or simulated research. Concerning the last criteria, the adequacy of the statistical procedures to the variables and to solve the research question, we believe that the good level demonstrated in both groups is highly associated to a lack of confidence of the students in this matter. Our experience tells us that students claim the teacher's counseling and approval before initiating the chosen statistical method.

We found several significant statistical differences, at a 0.05 level, between the real and the simulated projects groups. The simulated research project group accounts for better results concerning graphical representations and on the adequacy of statistical inference procedures (inferential tests – adequacy of hypothesis, assumptions and conclusions). It also demonstrated a better level of reasoning with statistical models.

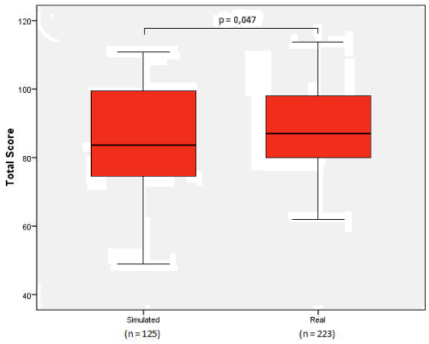
The real research project group demonstrated a significantly better performance on the recognition of the need for data (describing clearly the population, the procedures for data acquisition, the instrument and its validity and reliability) and in integrating statistics in the context of the research. This group achieved a better rate in all the items concerning the report evaluation – which requires synthesis abilities and demands pertinent communicative abilities - integrating statistics in context with higher success which is the ultimate goal of teaching and learning statistics.

Table 1. Item and Total Score mean (SD) in the whole sample and in both groups

	Range	**Total N=348 N=348**	**Simulated n1=125 Mean(SD)**	**Real n2=223 Mean(SD)**	**p value**
Sets the population clearly	1-5	4,09(1,26)	3,68(1,30)	**4,31(1,17)**	**<0,001**
Report: objectives description	1-5	4,68(0,61)	4,57(0,70)	**4,75(0,54)**	**0,013**
Definition of independent variables	1-5	3,52(1,35)	3,52(1,30)	3,52(1,38)	0,999
Definition of dependent variables	1-5	3,54(1,35)	3,52(1,30)	3,56(1,39)	0,812
Explains how the variables are important for the problem	1-5	4,01(1,27)	**4,18(0,87)**	3,91(1,43)	**0,032**
Describes how the sample is obtained	1-5	4,16(1,16)	4,17(1,00)	4,15(1,24)	0,870
Relevant sampling method	1-5	3,81(1,28)	3,72(1,29)	3,86(1,27)	0,339
Describes the procedures for data acquisition clearly	1-5	4,42(0,95)	4,18(1,09)	**4,56(0,84)**	**0,001**
Describes the instrument used with clarity	1- 5	2,72(2,27)	1,48(2,07)	**3,42(2,07)**	**<0,001**
Refers to the reliability of the instrument or estimates	1-5	1,81(2,12)	1,18(1,98)	**2,17(2,12)**	**<0,001**
Observance of the validity of the instrument	1-5	1,94(2,17)	1,21(1,99)	**2,35(2,17)**	**<0,001**
Graphics	1-5	4,13(1,11)	**4,3(0,72)**	3,92(1,44)	**0,019**
Central Tendency Measures	1-5	4,34(0,90)	4,08(0,89)	**4,48(0,88)**	**<0,001**
Dispersion Measures	1-5	3,78(1,29)	3,86(0,95)	3,73(1,45)	0,332
Hypothesis - Tests	1-4	2,94(1,04)	**3,64(0,52)**	2,55(1,06)	**<0,001**
Assumptions – Tests	1-3	2,48(0,77)	**2,75(0,37)**	2,34(0,89)	**<0,001**
Adequacy – Tests	1-3	2,93(0,34)	2,95(0,16)	2,92(0,40)	0,308
Conclusions – Tests	1-5	4,48(0,84)	**4,61(0,45)**	4,40(0,99)	**0,008**
Report: Communicating statistics	1-5	4,18(0,77)	3,84(0,77)	**4,36(0,70)**	**<0,001**
Report: Logical structure	1-5	4,57(0,66)	4,46(0,74)	**4,63(0,61)**	**0,035**
Report: Consistency in notation	1-5	4,67(0,63)	4,56(0,65)	**4,73(0,62)**	**0,017**
Report: Discussion appropriate	1-5	4,10(0,90)	3,85(0,92)	**4,25(0,86)**	**<0,001**
Report: Presents conclusions	1-5	4,08(1,07)	3,91(0,97)	**4,18(1,11)**	**0,020**
Report: Explain limitations	1-5	3,50(1,45)	3,30(1,27)	**3,61(1,54)**	**0,047**
Total Score	24-115	87,10(13,91)	85,50(14,84)	**89,14(12,39)**	**0,047**

As we can see in figure 1, students who developed real projects achieved a higher level of statistical competence when compared with the simulated research group.

Figure 1. Boxplots for the total score in real and simulated groups



CONCLUSION

Our results show that both groups of students, real and simulated project based, achieved a good level of statistical competence which allows them, in future, to carry out their own investigations. Nonetheless, the results regarding inferential statistics still transmit some weaknesses in inferential reasoning and on the perception of variation inherent to data. Consequently, their conclusions do not convey the required perception of uncertainty.

Students who worked with real data achieved a better level of statistical reasoning than students who performed a simulated research project. This reinforces the task to allow students to work not only with real data but with their own data collected by themselves.

New technologies and availability of data challenge statistics educators to contribute to students' self-efficiency and, at the same time, to develop a positive attitude towards statistics in students. The ability to take data, to understand it, to analyze it, to extract value from it, to visualize it, to communicate it - is a majorly important skill in our days and will continue to be so for health sciences' students. Students need to understand data, its inherent variation and how to extract value from it.

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