INCREASING SECONDARY STUDENTS' STATISTICAL KNOWLEDGE BY FOCUSING ON TEACHERS' ENGAGEMENT AT LAVRAS, MINAS GERAIS, BRAZIL

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A prospective exam was performed to quantify the statistical knowledge of students before they start attending classes in college. A four question test (two of probability and two of descriptive statistics) was given to 95 students of Federal University of Lavras and 87 students of three secondary schools (two private and a public one). The mean scores were not statistically different and were considered poor. It was suggested that this poor student knowledge might be due to poor knowledge of their teachers or a lack of motivation and interest. To attempt to correct for this, secondary teachers attended a one-day class given by the authors of this paper. By examining student scores from before and after that information transference, it was found that teachers that attended the class could transmit more information and enhance their students' scores.

INTRODUCTION

In this century one can observe an increasing development of Statistics due mainly to the scientific and technological demands of different science areas. It is justified by the science unity principle, defined as the requirement of "a uniform standard to hypotheses validation, independent of the knowledge area" (Harold Jeffreys), or as "the unity of the methods applied to analyze and learn through experiences and data" (Karl Pearson), in Pereira (1985).

Another important aspect, besides those formal scientific statements, is the fact that people encounter a great deal of categorical and/or numeric observation that, eventually, must be used to guide decisions. Basic statistical knowledge is necessary for all kinds of data interpretation. Here, we define basic statistical knowledge like knowing the contents of basic statistical books, like Magalhães and Lima (2002).

Further, the current society requires from the citizen abilities that allow him to understand his reality and be able to interfere on social actions. Probability and Statistics teaching, as well as other mathematical concepts mentioned at school, can provide appropriate tools to promote critical capability and autonomy (Lopes, 2004). Building critical thinking is mentioned by Innabi (2002): "The literature in critical thinking reflects big variations in its definitions of critical thinking and variations in how people look into critical thinking. In spite of that, most of these different views agree that 'statistics' or 'statistical thinking' or 'statistical ability' is part of the critical thinking skills or abilities."

It is worth noting that this requirement is already mentioned in *Brazilian National Curricular Parameters* (PCN, 1999), which remarks that contents of Probability and Statistics should begin at the fundamental teaching level (elementary school).

A Brazilian exam that is proposed to evaluate the general knowledge of the secondary students is called ENEM (National Exam of Secondary Level). It has five principal competencies, two of them highlight the ideas mentioned above:

- Select, organize, relate, interpret data and information represented in different ways, to make decisions and face problems, and;
- Relate information, represented in different ways, with available knowledge in concrete situations, to construct consistent argumentation.

However, in spite of what was stated above, students often get to college with insufficient (or even none) knowledge of probability, variability, random thinking, and serious language problems (Cordani, 2001). Given this reality, some questions are suitable, such as: How much scientific knowledge is been absorbed by the secondary students? How are Probability and Statistics being taught in secondary school? What is the teachers' knowledge and interest in these topics?

Based on these questions, we tried to begin to answer them by evaluating if students' knowledge of Probability and Statistics is sufficient when are have completed secondary school and when they are reaching college. If so, the college professors could begin teaching Basic Statistics with further topics. If not, some alternatives can be suggested that can minimize the topics that are not adequately covered in the teaching Probability and Statistics in secondary school. The practical part of this work was developed in Federal University of Lavras (UFLA) and some secondary schools of Lavras city, Minas Gerais, Brazil. This study was didactically divided into five stages, that are detailed below.

FIRST STAGE: MOTIVATION

The first part of this work was developed in the second semester of 2004. It tried to detect possible deficiencies in the teaching of Probability and Descriptive Statistics at the secondary level.

A sounding test was given to 95 students who had just entered UFLA during the first class of the discipline called Basic Statistics. The test was also given to 86 students in the last grade of secondary school. The test was composed of four questions concerning the following topics:

- Two questions on Probability: one about the definition and another using the jointed events concept;
- Two questions on Descriptive Statistics: one about mean, median and mode and another on graphical analysis.

Results were considered poor. For college students, the mean was 5.5 and for secondary school students the mean was 4.7 (n ranging from 0 to 10). They were considered not significantly different by a t-test ($t(\text{gl}) = 180$, p-value = 0.08) at the 5% level of significance.

Based on this indication of deficiency of the students from the secondary school, the second stage of the project was begun.

SECOND STAGE

The second stage of the project began with a meeting between a group of some post-graduate students in the course of Agronomy/Statistics and Agricultural Research (UFLA) and 41 secondary students (and 2 Mathematics teachers) of a public school.

That contact consisted of a two-hours class in which the post-graduate students presented a contextualized approach to Probability and Statistics basic formulae, in a critical discussion format. A test with two questions on Probability and two questions on Descriptive Statistics was given. Those results are not shown here because the intention was just to gather the reactions and impressions of the secondary students and their teachers about the class. If the impressions and results this kind of approach were good, the approach could later be transmitted to teachers so that they could improve their own classes. For this propose, the students filled out a questionnaire, and the answers are summarized in Table 1.

Table 1: Evaluation of the class ministered to 41 people from 3º grade of secondary school and Mathematics teachers

Questions	Great (%)	Good (%)	Fairly Good (%)
Practical content application, motivation.	39.02	56.10	4.88
Clear content transmission.	43.90	53.66	2.44
Domain of lecturers' content.	63.41	29.27	7.32
Concern with the class learning.	36.59	58.54	4.88
Communication and relationship with the class.	58.54	39.02	2.44
Learning with the class.	24.39	56.10	19.51

Looking at Table 1, one can see that the results showed that the students were receptive to the new approach used to present the content. This lead to the following thesis: *Deeply involved,*

motivated and technically prepared teachers can transmit concepts of Probability and Statistics in an efficient way producing better learning for their students.

THIRD STAGE

Under that new lens, we decided to work with teachers of Mathematics from first and second grades of secondary school. The success of that work would be reflected in the statistical knowledge of their students.

With this aim, a test was given to students from two of the three initial schools, one of them a public school (school A) and the other a private school (school B). In each one, a first and a second grade class was selected. The objective of this first test was to evaluate current knowledge (before any new approached class) of the topics:

- One question on Probability mentioning the *odds* concept;
- Three questions of survey analysis with surveys picked from magazines (a probabilistic sampling, a non-probabilistic sampling and a census).

For this qualitative test evaluation we assumed four classes of answers: Fully correct (F), Partially correct (P), Incorrect (I) and Fully Incorrect (FI). The first three categories referred to statistical coherence and last one referred to blank and incoherent answers.

To evaluate the results the scores were grouped into two classes: "F or P" and "I or FI," and transformed into proportions. Proportions of "F or P" (highest scores) were statistically compared to 0.5, by an unilateral *Z* test (in a two proportions case it is equivalent to do a chi-square independence test), with 5% of significance. Assuming independence, proportions of schools A and B, and first and second grades, were compared, by an unilateral *Z* test, with 5% of significance (Triola, 1999).

The results of the hypothesis test comparing schools A and B, and their proportions to .5, are shown in Table 2. Note that p_A and p_B refer, respectively, to schools A and B, respectively. Note that there are tests along the rows and at the bottom of the first column.

Table 3 shows the comparison between first and second grades of secondary school, referred by p_1 and p_2 respectively.

Table 2: Proportions equality test between schools A and B – 1º exam

1º Exam	F or P	p-value	Alternative Hypothesis
School A (p_A, n = 264)	0.299	*< 0.0001*	$p_A < 0.5$
School B (p_B, n = 284)	0.563	*0.016*	$p_B > 0.5$
p-value	*< 0.0001*		
Alternative Hypothesis	$p_B > p_A$		

Table 3: Proportions equality test between 1º and 2º grade – 1º exam

1º Exam	F or P	p-value	Alternative Hypothesis
1º Grade (p_1, n = 272)	0.511	*0.642*	$p_1 > 0.5$
2º Grade (p_2, n = 276)	0.362	*<0.0001*	$p_2 < 0.5$
p-value	*0.01166*		
Alternative Hypothesis	$p_1 > p_2$		

Verifying the p-values on Table 2, one can note that in school A the students had an unsatisfactory performance, since the group of scores "F or P" are less than 0.5 (not casual). It was the opposite of what happened in school B. Scores "F or P" were even greater in school B than school A. This kind of result was not surprising since B is a private school and can offer better teaching conditions, despite the good will of public school (A) teachers.

A really surprising result, shown in Table 3, is that the students from the first grade demonstrated a better initial performance than those from second grade (in both schools) where we had expected that more mature students would show a better performance.

In general, the performance was considered unsatisfactory. This lead to the fourth stage, aimed at testing our thesis that prepared and motivated teachers will have enhanced results.

FOURTH STAGE

Based on all information gained at previous stages, a three hours informal meeting between the authors of this paper and the teachers of two (involved) secondary schools was held. Unfortunately, just second grade teachers (of both schools) came to that meeting.

The first step was to discuss the same questions the students had answered (at the previous stage) and ask the teachers to try to answer them too. After, the following topics were then discussed:

- Role of Statistics in Science: a philosophic approach;
- Some aspects of PCN's and ENEM;
- Probability: *odds* concept, union and intersection of events;
- Sampling: probabilistic and non-probabilistic sample, sample size, estimative error, intuitive decision making;
- Interdisciplinarity.

All discussion was conducted through a critical discussion of Probability and Statistics, i.e., without a too formal language, highlighting the importing of contextualization, globalization and the interdisciplinarity that those contents can supply. The importance of the teachers engagement and motivation on knowledge transmission was emphasized.

Teachers were requested to transmit this content and approach to the other teachers (of first grade) that could not be present at the meeting.

FIFTH STAGE

Initially, teachers transmitted to their students what was discussed at the informal meeting and a second test with the same structure and the same correction criterion was given. The same hypothesis *Z* tests were used to compare proportions between schools (Table 4) and grades (Table 5). One should note again that the tests are done both along rows and columns.

Table 4: Proportions equality test between schools A and B – 2º exam

2º Exam	F or P	p-value	Alternative Hypothesis
School A (p_A, n = 228)	0.462	*0.125*	$p_A < 0.5$
School B (p_B, n = 248)	0.629	*< 0.0001*	$p_B > 0.5$
p-value	*0.003*		
Alternative Hypothesis	$p_B > p_A$		

Table 5: Proportions equality test between 1º and 2º grade – 2º exam

2º Exam	F or P	p-value	Alternative Hypothesis
1º Grade (p_1, n = 236)	0.583	*0.005*	$p_1 > 0.5$
2º Grade (p_2, n = 256)	0.516	*0.304*	$p_2 > 0.5$
p-value	*0.136*		
Alternative Hypothesis	$p_1 > p_2$		

Considering 5% of significance, one can observe that school B remains better than school A; and the second grade became statistically equal to first grade.

Finally, the scene before and after the informal meeting was compared by testing the equality of proportions on schools and grades (Table 6 and 7).

Table 6: Proportions equality test between 1º and 2º exam in schools– by F or P criterion

F or P	1º Exam	2º Exam	p-value	Alternative Hypothesis
School A (n = 188)	p_{1A} = 0.299	p_{2A} = 0.462	*0.012*	$p_{1A} < p_{2A}$
School B (n = 316)	p_{1B} = 0.563	p_{2B} = 0.629	*0.116*	$p_{1A} < p_{2B}$

Table 7: Proportions equality test between 1º and 2º exam in grades– by F or P criterion

F or P	1º Exam (p_{T1})	2º Exam (p_{T2})	p-value	Alternative Hypothesis
1º Grade (n = 272)	p_{11} = 0.511	p_{21} = 0.583	*0.116*	$p_{11} < p_{21}$
2º Grade (n = 232)	p_{12} = 0.362	p_{22} = 0.516	*0.010*	$p_{12} < p_{22}$

One can note that there was no change at school B, as with first grade. But at school A and in second grade, there was a enhance after the meeting. It is worth remembering that the only teachers that came to the informal meeting were second grade teachers (which may have contributed to the improvement in scores). This fact corroborates the thesis of this paper: Teachers $\Leftrightarrow$ Suitable basic knowledge on Probability and Statistics $\Leftrightarrow$ Motivation $\Rightarrow$ Good learning of the students.

It is important to note that the change of the educational practices and the attitude of a person towards content need time to be done. Therefore, a single meeting can be enough to motivate, but not to change the practices and, consequently, to create didactic conditions to increase the student's learning potential.

CONCLUSIONS AND FUTURE WORK

One can highlight some interesting aspects, as follows:

- Students who have just entered into college and third grade students of secondary school showed a deficiency in Probability and Statistics notions, with a mean score 5.1 in a preliminary test.
- An informal meeting between the post-graduate students and secondary teachers of Mathematics to discuss some aspects and concepts of Probability and Statistics can generate a good effect upon secondary students' learning, associated with the motivation level of their teachers. That discussion, proposed at the fourth stage of this paper, should focus on contextualization, globalization and interdisciplinarity.
- There are differences between private and public teaching conditions, despite the good will of the public school teachers.
- Working without too much formalism in teaching Probability and Statistics seems to produce good results in first and second grades of secondary school. This way, one can hope that students can enter college with a critical view of their life and science, and, eventually, college professors can start disciplines like Basic Statistics at a further point.

However, this paper does not intend to finish the discussion of this kind of approach, but rather start a larger discussion about ways to motivate and prepare secondary teachers, like other disciplines on courses of Mathematical licentiateship, or even how these themes can be approached in didactic book for secondary school.

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