TEACHERS TRAINING IN A REALISTIC CONTEXT

Ornella Giambalvo[1] and Linda Gattuso[2]
[1]Università degli Studi di Palermo, Italy, [2]Université du Québec à Montréal, Canada
giambi@unipa.it

There is an important need to prepare preservice teachers for the teaching of statistics. We will describe an experiment set up to achieve effective teacher training in statistics in the setting of an Italian university. Student–teachers had to prepare lessons using a real data set collected from the Italian mail services. Not only did they look into all the usual basic concepts of statistics, but they also questioned and dealt with doubts and errors their pupils put forth. They discovered the richness of the concepts, the content of descriptive statistics and the basic analyses of observed data. This experiment showed that the data, although very simple, is rich and productive, and that effective teacher training can be set up even with modest resources when there is determination and motivation.

OVERVIEW

In the last two decades, great developments have been made in the research of statistics education. It has been established that for the majority of the students conceptual understanding is more important than computational skills. Many studies, particularly those regarding the development of statistical thinking, suggest that students should go through the same procedure as statisticians and learn using real data, analyzing it to answer questions with the help of various computational tools, and communicating their results. This requires a transformation of teaching and consequently of teachers' preparation. Statistics is generally part of the mathematics curriculum, and is therefore managed by mathematics teachers. Teachers having training in mathematics are seldom prepared to deal with statistical instruction, as many do not have any training in statistics or statistics teaching. Also, many education programs for preservice teachers do not prepare for teaching statistics (Craven, Gattuso & Nicolson, 2006). More and more, statisticians and statistics educators are addressing the problem, and some very interesting experiments have been developed to answer the particular needs both of inservice and preservice teachers. In this paper, we describe such a pedagogical experiment.

BACKGROUND

Undergraduate courses in statistics are widely available but seldom respond to the needs of teachers. Too often they are theoretical and mathematically inclined; consequently, they do not give an adequate idea of the practice of statistics that the teacher will have to teach and "students often leave this course with less intuition and conceptual understanding than students who have taken a lower level course" (Rossman & Chance, 2002). However, teachers are asked to teach statistics for understanding, so it is essential that they experience the same process as their students. They must experience an active exploration of statistical concepts (Kader & Perry, 2002; Makar & Confrey, 2004). In order for teachers to provide these kinds of tasks for their students, they need to develop their own statistical understanding. It is not only important that they have a sound knowledge of statistics, but it is also necessary that their training includes the study of statistics along with the study of how to teach it (Kader & Perry, 2002). As shown by Mickelson and Heaton (2004) knowledge and skill do not automatically transfer into teaching. An overview of various experiments in teacher training points out some principles similar to the ones put forward for teaching statistics in schools (Friel, Curcio & Bright, 2001; Kader & Perry, 2002; Rossman & Chance, 2002; Cobb & McClain, 2004; Makar & Confrey, 2004).

To begin with, everyone agrees on the need to use real data. The next task is to formulate a question and choose the necessary variables to answer it, and, if needed, to extract them from the data collected. The exploration and organization of the data should lead to interpretation and to the discovery of links between the variables. Various representations should also be part of the exploratory analysis, depending on the nature of the data and of the

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questions. The opportunity to compare more than one distribution is highly recommended (Konold & Pollatsek, 2002; Makar & Confrey, 2004). Dealing with various computational tools will facilitate and complete various exploratory analyses. Finally, it will be possible to make sense of the analysis and interpret the results in order to produce significant statements that address the question.

One way to do this is to have the students play the role of the learner and the teacher at the same time, going through an "actual teacher as learner practice" (Vithal, 2002). The student teachers learn to teach statistics through a project where they experience both sides of the situation, learning to teach statistics by going through a pedagogical approach they may not have come into contact with as students.

> During the time that the projects run, the teacher educator takes different roles as a resource person, facilitator, supervisor and teacher - making suggestions, reviewing data collection instruments … creating opportunities for using computer software for data analysis and presentation (Vithal, 2002, p. 2).

This approach provides an excellent balance between "traditional" theoretical training and in-school practice. The traditional course often remains a theory that seems too far from the reality of the classroom and does not transfer into the actual practice of the future teacher. On the other hand, practice in a classroom does not allow time to reflect and analyze the content because the student teacher is overwhelmed by the practical aspects of the situation and will, more often than not, refer to his past experience as a pupil and not consider any innovation. However, if he had the chance to go through such a project as a learner and at the same time look at it from the point a view of a teacher, chances are that he will try it out in his own classroom. Although a training situation following these principles may be achieved with more or less resources, it requires a lot of willingness and personal commitment on the part of the educator. We will describe an experience based on these principles that was set up to achieve effective teacher training for statistics in the setting of an Italian university.

A TEACHER TRAINING EXPERIENCE IN ITALY

In Italy, experiments conducted by the Centro interuniversitario di ricerca per la Didattica delle Discipline Statistiche (CIRDIS) and the Istituto Centrale di Statistica (ISTAT) found that the learning of basic statistical concepts is related to the use of real data (DOA) and to true motivation on the part of the teacher (Ottaviani & Silvestri, 2001; ISTAT, 2004; Giambalvo, Milito & Oliveri, 2006). They also initiated the production of new material for the teaching of statistics, particularly a database in an area close to the student's environment, useful for statistics lessons in school.

In Italy, secondary school mathematics teachers have a university degree in mathematics or engineering (4 years) when they enter the "Scuola di specializzazione" for a two year program (15 hours per week). In the first year, the courses are on subjects not previously studied and also on pedagogy and education in general. In the second year, for six months, they take teaching courses in a choice of different subjects, one of them being statistics. Finally, for the last six months, student teachers go into schools for their teaching practice. Overall, as elsewhere, there is little room and resources allowed for the teaching of statistics. It was therefore necessary to create an environment that required little but would be efficient for the training of preservice teachers.

Starting with the fact that DOA is efficient for the teaching of statistics in schools, it was decided for the experimental course in teaching statistics to transfer this method to preservice teachers and to use the data developed by the CIRDIS. These data were collected from information on the mailing of letters. Members of the Cirdis of four universities mailed two letters (ordinary and priority) each morning to the three other centers for nine days including Saturdays. Each correspondent wrote the date of mailing on the envelope and, at the other end, the date of reception was recorded (Brunelli, Giambalvo, Lombardo & Rigatti, 2004). The resulting data are at the same time very simple and also very rich in information that can generate questions. For example, the mean of the number of days for delivery of the OP (ordinary mail) and PP (priority mail) should be the same between Palermo-Roma and Roma-Palermo but it isn't, why? Are there any statistical instruments useful to ascertain this difference? Not only was the new data available for teachers on the website, but this experiment set off a reflection on the use of data for teaching, an a priori analysis (Giambalvo, 2004) that revealed more on the potential of the data matrix as a basic material for teacher training.

At the University of Palermo, only about one third of the students in the teacher training program that are enrolled in the teaching of statistics course have taken a statistics course in the first year of their training. Because their high school training in statistics is limited to descriptive statistics introduced in the mathematics course, their knowledge of statistics is minimal.

DESCRIPTION OF THE COURSE

The statistics training course started with a talk on the importance of statistics in today's world and the necessity of allowing a significant place for the subject in schools. This was followed by two or three lessons used to update the students' knowledge in basic statistics. The class being small (~20) this could be done in discussion format. The class was then divided into groups of four, with at least one student who had taken a statistics course the previous year.

Each group was asked to prepare a lesson on one of the pre-chosen topics for teaching statistics in the setting of a secondary school classroom using the mailing data. The topics previously chosen were: a) organization of tables and graphics, b) central and position measures, c) variability, and d) relation between variables. After discussing this proposition, a fifth topic emerged: the use and informative potentiality of the data. This topic required extraction of more information from the data, and it became topic number one because the results of this topic affect all the others. This subject was assigned to the group, including students who had a more formal approach, in the hope that they would apply another point of view since they could not rely on formulas and calculations.

One of the aims of the course was to show students how to work so they could transfer the mode of functioning to the planned teaching of each concept. The students worked in class, and the teacher was always there, available to provide information but also to raise questions and suggest paths for solutions. At the start, the teacher emphasized the fact that each theme was not independent from the others, but that they were linked, and the concepts students were working on must be linked with the previous ones. During the course, it was the teacher's role to inform the whole class on the progression and results of the work done in each group. The students had to explore each concept, consult textbooks or references from different sources and use computers, particularly spreadsheets (Excel), to explore the data. At the end of the course, there was a presentation; some groups explained their work, and others presented their lesson so that each student was acquainted with the work of each group.

DESCRIPTION OF THE STUDENTS' ACTIVITY

Students working on topic one, the use and informative potentiality of the data, were at first a little lost but rapidly outlined two points: the treatment of the data and the extraction of useful information. For the first point, they discussed the value of the data. For example, does "three days for a letter from Palermo to Rome" (furthest cities) have the same value as the "three days from Rome to Perugia" (closest cities)? Right away they associated time and space. They recognized a qualitative value of the quantitative data. Also, could the three designating the third biggest city (a ranking score) be treated mathematically the same way as the three of the time interval (continuous variable)? Secondly, they understood that the path to teaching statistics went through the definition of the aims of the survey, and that the available data were not always sufficient. They began to see that it was not always possible to calculate a mean and that statistics offered alternatives for answering various questions, sometimes due to the typology of the variable (qualitative or quantitative, etc). For students in mathematics, this was a big discovery. They were more ready to adapt a Gaussian curve or calculate the mean and estimate the regression line; the rest didn't count!

The topic on organization of tables and graphs was easier because it was more familiar. Starting with the original data supplemented with new information, the students proposed new procedures to obtain a better understanding of the mailing service. Pressed by the requirement to synthesize the data through tables and graphs, they reasoned by providing a synthesis of the information taking into account the inevitable loss of information. The practical outcome of this reasoning led to the choice and production of tables and graphs to explain the phenomena, but most of all, the student teachers recognized the importance of these tools because they provide easily readable information. To construct various representations, they had to make decisions about the type of tables and graphs to use, considering the information to be presented, the distribution, and the answers to questions such as: "Which is more convenient: ordinary or priority mail?" "Which city is more efficient in delivering the letters?"

The topic on central and position measures was also familiar but was in some ways more difficult because of previous conceptions and sometimes inadequate knowledge. The synthesis in the tables and graphs proposed reflections and compared statistical strategies to obtain the same information. The preservice teachers, observing the data in the tables or on the graphs, could answer some questions such as: (a) Which way is faster?, (b) Which city received more letters on Tuesday?, (c) What is the maximum time for the reception of 50% of the letters? 25%? 10%?, and (d) On which days is it better to mail a letter? But if a graph was sufficient for the first question, they gave only an approximate answer for the others. The need to calculate an average or maybe a median or a more appropriate mode arose in trying to answer questions. The mailing data gave the opportunity to deal with outliers and to discuss their effect on the average.

Because the concept of variability is strongly linked to the mean, the teacher suggested considering variability as a mode to validate the mean because it answers the question: how do data vary from the mean value? Students observed the difference in the means, with or without the presence of an outlier. The idea of calculating the range came up, but the range does not consider the variation of data between the minimum and maximum values. A way to do it would be to analyze the distance between each value and the mean; however the sum of all these differences (considered as a synthetic measure) is always 0, so it was decided to square the differences in order to solve the problem of negative and positive differences. This variability index is appropriate because the $(\sum(x-\bar{x})^2 = \min)$ insures that variability will not be overestimated (they tested it with the available data). Finally, they developed the variance, the "mean" of the squared differences between the values and the mean.

The fifth group had to produce material for lessons on the relations between the variables and had to take into account the preceding topics that would have revealed links between concepts (questions, aims) and instruments (graphics and tables with the average, average with variability, etc.). First they extended this to two or more variables, producing, for example, two-way tables. The variables most often used were *city* and *time of mailing* although other variables such as *time* and *space* were also handled. Students noted that to find the average time for each city they had dealt with two variables, and they realized that the concept of relation was fundamental. From there, the concept of variance was extended to covariance and correlation. The teacher encouraged them to also look at relations between qualitative variables. A simple comparison of the relative frequencies, with two-way tables, led them to answer questions such as "Is there a relation between the presence of an airport and the rapidity of the mail?"

RESULTS

This experiment was repeated for four consecutive years in difficult conditions (classroom not adapted for group work, computers full of viruses, etc.), but these conditions did not impede student involvement and desire to go on with such an experience. The results were more or less the same each year. The reaction of the students and their understanding of statistics were quite positive each year, but we noted differences depending on the argument treated. The first group (use and informative potentiality of the data) needed more help from the teacher to transform the ideas into variables. But after some difficulties, and because they could not rely on textbooks, they realized the importance of this preliminary work on the data. At the beginning, they thought they were not doing any statistics but only losing some precious time. At the end, they let go of their preconceptions and understood that this phase of comprehension of the data is indispensable and, moreover, that statistics consists of reasoning without which computation does not make sense. The second group (organization of tables and graphics), who knew Excel and thought they knew everything about tables and graphs, rapidly encountered conceptual difficulties. They constructed beautiful graphs; however, these graphs were not associated with meaning or were too complicated to read. The textbooks consulted used different symbols or terminologies that had to be standardized. A discussion between the groups was very helpful to get some uniformity. Difficulties encountered by the third group (central and position measures) were relative to the concept of arithmetic average and median, seen in relation to a function of distribution. A very animated discussion occurred before the group concentrated on the importance of interpreting the mean or median instead of finding a point on a graph. The fourth group (variability) thought that their topic was trivial and that there really was not material for lessons, so their work was finished. It took them time to see that variance is an average and recognize its importance. They finally saw that they could start with the properties of the average, and they went on with more enthusiasm. The fifth group (relation between variables) complained more. They all had a degree in mathematics and instinctively started with the regression, which was easy for them. However they saw that it was not adapted to the variables: they had trouble giving a meaning to the slope of the regression. In the end, they switched to two-way tables.

One course aim was to involve every single student, and the results were generally positive. The work of the groups was presented to the class, with the person presenting chosen by the teacher, and was followed by a discussion. Afterwards, a teaching simulation was carried out with one student giving the lesson and the others acting as pupils. The questions and observations of the students-pupils were very stimulating and helped them see that a statistics lesson may be an occasion to deal with many arguments from different points of view. Going through this activity, the students realized by themselves the importance of statistics and the fact that statistics could not be reduced to a list of formulas or to the use of Excel, but that it required reasoning. It is hoped that they will teach as they learned, in an interactive mode starting from a problem-solving situation, knowing that all concepts are related and that the different statistical tools are complementary. They realized that they could not limit their teaching to a technical or computing aspect, and that meaning, reasoning and interpreting are more important. The standard course evaluation gave excellent results. Interest and motivation were very high, the students were very punctual and would not even stop for the break. They also verbally expressed their appreciation, asking for more time. They particularly valued the laboratory format of the course, stressing the fact that most of the courses are too theoretical and formal.

CONCLUSION

This experiment shows that effective teacher training can be set up even with modest resources where there is determination and motivation. One of the strong points of the experiment was the use of data coming from a real experiment, even if it was not collected by the students due to a lack of time. Not only were the data about the Italian mail service simple, easily processed and close to the students' environment, they also provided an excellent and rich context for the teaching of statistics. Real data coming from a concrete experience favors learning of statistical concepts and procedures, and the DOA approach encourages statistical reasoning. The contents are contextualized, and their management becomes active and creative. A second point is the involvement of a statistician in teacher training. This is in some ways a strong point because the statistician brings not only theoretical matters but also important professional practical first hand experience. However, it is also a weakness because many statisticians are theoretical and not interested in either teacher training or in research on the teaching of statistics, which is not well regarded in the academic world. Finally, not all students respond positively to this teaching style. Some would prefer a more theoretical approach: for instance, they would like to learn more probability theory. They don't understand that the aim of the course is the teaching of statistics in high school and not a course for mathematicians or physicists.

There are some limitations to this approach. Twenty-five hours is not a lot of time to carry out this type of work. Many interesting ideas on the possibilities for teaching statistics cannot be deeply explored. Depending on the groups, it is a risk to emphasize a result or a topic and to neglect others. For example, one year it took more than one lesson to explain that the median is a point of the distribution and the relation between mean and variability. It is not always possible to foresee how certain topics will develop. The teacher can interfere, but should avoid doing so as discussions are fruitful and make the student-teachers understand how difficult it can be to teach statistics.

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