THE EFFECTS OF SOME TEACHING TECHNIQUES ON LEARNING STATISTICS

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This paper describes the main results of a research project carried out in Italy at every school level to compare how different teaching approaches influence the students' learning process. The experiment involved more than 6000 pupils (age 6-19) at every school level and 338 teachers.

INTRODUCTION

The importance of the role of statistics in the educational process has now been recognised and is confirmed by the introduction of the discipline in school curricula at all levels, both in Italy and abroad. This evolution in the educational process is also justified by the awareness that in a modern society statistics is becoming a *new technical language* necessary to exchange quantitative information (Galmacci & Milito, 2000).

During the long debate within the international scientific community on teaching statistics new elements of discussion emerged, mostly concerning the modified social conditions of pre-college teaching, the growing expansion of new technologies and the latest pedagogical theories. In a modern perspective, considering the fact that statistical information is an indispensable instrument for every citizen to exercise social control democratically and to carry out rational choices, it has become a real necessity to supply precise objectives and targets for the teaching of statistics.

The scene in Italy, which is more or less the same as in other countries, consists in teachers who lack specific training, in seriously inadequate textbooks, in teaching supports (e.g. software) whose effectiveness has never been assessed, finally in students who are not capable of dealing properly with problems of quantitative character (incapacity of reading and interpreting statistical tables, charts and graphs, of catching the meaning of phenomena like variability, etc.). It was assumed that the essential elements for adequate learning were i) sufficient teachers' knowledge, ii) high quality teaching materials, iii) teaching strategies focusing on students. A significant contribution in that respect has been given in 1997 by David Moore who, among other things, says "...the most effective learning takes place when content, pedagogy and technology reinforce each other in a balanced manner"(p.124). This paper describes a project aimed to set up efficient approaches, strategies and materials to teach basic statistical concepts and to carry out an experimentation to compare the various strategies.

THE PROJECT

During two years (1999-2000) a group of Italian researchers (thirteen statisticians, three psychologists and two pedagogues) carried out a national project for teaching statistics, funded by the Ministry of Universities and Scientific and Technological Research (MURST) and by the Universities of Padova, Palermo, Perugia and Roma "La Sapienza". The project was aimed mainly at studying the efficacy of different teaching approaches for statistics at every school level: primary (6-10 years old), middle (11-14) and high schools (15-19). A preliminary study, concerning both the teaching approaches used by teachers and the available textbooks, confirmed the fact that statistics were generally presented by focusing on theoretical (mathematical) aspects without considering their practical relevance and the interpretation of results. Afterwards, taking into consideration that the understanding of the role of statistics and the introduction of their basic concepts can be made easier by using real data related with daily life situations in which students can be personally interested or directly involved, new experimental teaching materials have been prepared using the so called Data Oriented Approach (DOA). This approach, from our point of view, could simplify the learning process of many theoretical and formal elements, introduce pupils to analyse data critically and answer statistical questions about the phenomena.

In regard to the choice of a statistical teaching methodology, we took into consideration the actual tendency towards the constructivist pedagogical model as it privileges active learning as well as consistency in the learning/teaching process. Also, concerning the use of new

technologies as teaching supports, it can be said that this sector is very dynamic and gets richer and richer with new ideas and tools, which often avail themselves with Internet resources. The "glamour" and attraction of software applications is always strong. Nevertheless, a spontaneous question arises: is the technology fashion the prevailing factor encouraging the development and the use of those tools, rather than their teaching effectiveness in the training process? This subject has been widely discussed by Currall (1997), and Galmacci (1998): the usefulness of statistical software for computational purposes is obvious but it is not evident that it plays the same role in the concept learning process.

One of the main goals of this project was to study how different teaching strategies (experimental factors) influence the students' learning process. The strategies proposed, always based on DOA, were different depending on the school level: concept mapping and didactic skills for primary schools, traditional teaching (TT) and Cooperative Learning (CL) pedagogical model (Johnson, Johnson & Holubec, 1994; Comoglio, 1998) for middle schools and, finally for high schools, traditional teaching, TT plus Lab activities, and TT plus CL plus Lab activities. A group of psychologists and pedagogues joined the research group from the beginning to plan the CL approach, assuming the teachers' training, the conception of the material (guides, tests, etc.) and of the class activities.

While planning the experiment, the whole research group deeply discussed how to recruit teachers, and then schools and classes, in order to use methodologies to control experimental and sub-experimental factors, but in practice any kind of randomisation was almost impossible. In fact, the experiment required teachers to attend training courses and do a lot of extra-work to set up lectures, lab activities and CL sessions (consider that training and extra-work was progressively harder and harder moving from TT to more complex strategies). Generally, we had to accept teachers on a "voluntary basis", that is, only the ones interested and available for the different levels of effort. Therefore, we must look at this "experiment" as a *quasi-experiment* in the sense of Cook and Campbell (1979). The research has been carried out within the activities of the CIRDIS (Inter-University Centre of Research for the Teaching of Statistical Disciplines), a centre promoted by the Universities of Padova, Perugia, Palermo and Roma.

THE EXPERIMENTATION

The working theme has been chosen taking into account the DOA approach as well as the fact that data collected by students in their own classes using a questionnaire should be "the same" available from ISTAT (the Italian Official Statistics Institute). For this reason, we chose the theme *Investigating Some Aspects of Everyday Life*; detailed teacher guides, organized into teaching units, and students working sheets (practical activities, exercises, etc.) were prepared to guarantee a homogeneous teaching approach.

The main statistics topics were: data collection (quantitative and categorical data), one way and two ways frequency distributions, graphics, measures of central tendency, variability. The data collected during the experimentation vary depending on the school level, however the information generally available concerns teachers' profiles, city, kind of school and students' assessment. Teachers' profiles were obtained through a questionnaire filled before the training period (to ascertain teachers' vocational experience, their motivations for participating to the experiment, attitudes towards statistics, etc.) and by structured interviews (before training and after the experimentation). During the experimentation, teachers have kept a diary recording all the activities and observations (the CL experimental group diary was much more analytic). Students' assessment has been carried out by means of achievement tests and, in middle schools, also by a logical aptitude test.

The experiment involved globally 338 teachers and 6143 students in 5 different regions of Italy (Oristano, Palermo, Roma, Umbria and Veneto). More precisely, we had 145 teachers and 2,129 pupils from primary schools (age 6-10), 86 teachers and 1514 pupils from middle school (age 11-14) and 107 teachers and 2500 pupils from high school (age 15-19).

Primary Schools

The experimentation carried out in primary schools differed from the others in many aspects, first of all because of the age. Previous other researchers (Perelli D'Argenzio, Rigatti

Luchini & Moncecchi, 1998) showed that, while pupils have no problems with calculations (namely, statistics computation), they have many difficulties in interpreting the results and in understanding their meanings. Starting from this point, the group responsible for this part of the project (M.P. Perelli D'Argenzio, S. Rigatti Luchini and G. Moncecchi) decided to focus the experiment on the *concept nets*. After a training period of more than 30 hours, teachers were introduced to basics Statistics as well as to some psycho-pedagogic elements linked to the Statistics contents taught at primary school and to the concept maps model: concept map, semi-structured class interview, concept net. The teaching units were organized, adopting suggestions from Pereira Mendoza and Dunkels (1991) and Dunkels (1999), for three levels: 6-7 years, 8-9 years and 10 years. The evaluation tests were prepared for five levels: one for each grade. In the classes involved with concept maps, teachers had to perform two class interviews: one at the beginning of the statistics activity and one at the end, to compare the ideas that pupils had developed.

The analysis of the achievement tests showed that, on the whole, pupils that have been taught with the DOA approach did a bit better than those following the concept maps teaching. On the other hand, a deeper analysis of the more conceptual items revealed better results from pupils that had concept maps teaching (Rigatti Luchini, Perelli D'Argenzio, Moncecchi & Giambalvo, 2000; Milito, Pannone & Rigatti Luchini, 2001). This suggests that other assessment methods have to be designed to evaluate if, and to what extent, the concept-map teaching method is more efficient than the traditional method in facilitating pupil's construction of statistical concepts.

Middle Schools

The group responsible for the middle school project included three statisticians (O. Giambalvo, A.M. Milito and A.M. Parroco) and three psychologists (T. De Caro, S. Di Leonardo and M. Marsala); they planned the experiment, the materials, the teachers' trainings (30 hours for the DOA group and 36 hours for the DOA plus CL group, both split in two steps) and, finally, all the assessment instruments. The experiment in the classrooms started at the end of March 2000 and lasted approximately 18 hours for the DOA group and 20 hours for the DOA plus CL group, spanned over two months. The assessment instruments were constructed and adapted to evaluate the entire experience of the experiment, both from the point of view of the teachers and of the pupils involved in it (Marsala, Milito & Parroco, 2000). In the present work we will only analyse the instruments that allowed us to gain an insight into the effects of the training on the teachers and into its results on the learning of statistics in the pupils.

The teachers were all given a scale test measuring their attitudes towards statistics on two separate occasions: before and after the training course (BTC and ATC), to detect any changes in opinions and attitudes, most probably resulting from their experience of the course. On the whole the training course produced a slight change in attitude towards statistics (approximately 65% of teachers showed a more positive attitude). The most evident positive change was seen in Palermo, while the changes were less evident in Umbria and Veneto. A slight decrease in the mean scores was found in Rome. The teachers who carried out the experiment using the CL had higher pre and post course scores than colleagues using the traditional method.

Another instrument potentially useful to indirectly evaluate the effects of the training on the teachers from the point of view of the learning of statistical topics was the achievement test given to the pupils, as well as the diary, which the teachers were required to keep during the classroom experimentation. From the diaries it emerged that although the teachers who used the CL method had attempted to follow the set guidelines of the new methodology, this did not always lead to a real change in the individual teacher's basic approach and this led us to critically re-evaluate the preparatory course. We were aware that the limited number of hours at our disposal, being restricted by the overall organisation of the project, which also had to include the time set aside for the experiment itself, would not allow a true "training" in the new CL method. If by the term training is, in fact, meant, and as we mean it, an activity aimed at producing a change, and thus at affecting both the sphere of "knowing how to do" (the techniques and strategies) and that of "knowing how to be" (the mental attitude) it should come as no surprise that the change was only a partial one (De Caro & Giambalvo, 2001).

As regards the analysis of the data about the effects on the students obtained by only evaluating the achievement test (it must be remembered that other instruments were used contemporaneously, but due to lack of space they will not be dealt with in this paper) it is interesting to observe that a number of systematic errors cropped up in the results of the achievement test, which suggest that some teachers had only partially assimilated the statistical contents of the training course (c.f. for example errors in: median, histograms and variability).

If we compare the results to determine the effects of the two different teaching strategies, it can be seen that, on the whole, in all the pupils participating in the experiment the scores were distributed in a negative asymmetric pattern and the mean score for the achievement test after CL was higher than after the traditional method (similar variability). In particular, this difference in scores was found in the schools of Umbria and Veneto (a difference of about four points), while in Palermo and Rome the highest scores were obtained by pupils taught with the traditional method during the experiment (Marsala *et al*., 2000).

One aspect which we felt merited further investigation was whether the results of the experiment were also linked to a favourable attitude of the teachers towards Statistics, and we thus looked for a link between the differences in the BTC and ATC attitude scale test scores and the results of the experiment measured by the achievement test for the two different teaching methods. The analysis suggested that there is indeed a link. On the whole, in 71% of the teachers whose pupils had positive results in the achievement test (i.e. they obtained a score higher than the mean) there was also a positive difference between the ATC and BTC scores. Of the teachers who obtained a positive result, it was the teachers from Palermo who showed the highest increase between BTC and ATC scores, using the CL method, whereas the worst results were obtained in the teachers from Rome, who had used the traditional method.

Apart from the analytical results on the difference between the two strategies used, it seems opportune to discuss in detail some interesting points arising during the experiment, and especially from the teachers' observations. As regards the experimentation using the DOA approach, it offered "inherent elements of considerable quality for pupil development" and in particular, from a teaching point of view, it "redefined the learning process, taking advantage of the natural curiosity of the pupils and their motivation at being made responsible for their own learning". It was also said to "put the intervention into context i.e. presenting concrete areas of interest and needs on which to pin the educational initiative, associating offers, methods and means". As concerns the difficulties and positive aspects of CL, the following also emerges from an analysis of the diaries kept during the experimentation. (De Caro & Giambalvo, 2001)

From the point of view of the teacher the difficulties consisted in: i) the change in role (from dispenser of knowledge to guide-organiser); ii) the need to reflect on and prepare material according to processes of logic which were to be precise but not established in advance; iii) organising and guiding a project the conclusion of which was not known right from the start. The *positive aspects* were: i) the satisfaction of seeing pupils working with great interest and drawing on previously unimaginable energy and resources; ii) the joy of seeing pupils "discover" the solutions to the proposed problems by themselves; iii) seeing day after day the positive changes in interpersonal relations within the CL group, changes which certainly facilitated the understanding, albeit partially, of the topics proposed in the case of pupils with learning difficulties, and aroused interest in the others who are normally subjected to an *ex-cathedra* lesson.

From the point of view of the pupils, the d*ifficulties* met with were: a) the change in role (passive - active); b) the responsibility of having to manage the activity proposed using their own initiative and as a member of a group; c) keeping up with the pace of the group (pupils with learning difficulties); d) making themselves understood by the group; e) reaching an agreement within the group. The *positive aspects* were: a) discovering new resources in themselves; b) personally managing the teaching activity, satisfaction in doing things on their own; c) the acquisition of a valid working method; d) personal maturity in relationships with peers and collaboration.

High Schools

The experiment for high school, planned and realized by six statisticians (L. Brunelli, G. Galmacci, L. Gattuso, M.G. Ottaviani, M.A. Pannone and M. Sernini) and two pedagogues (S. Casucci and M. Striano) consisted in three different teaching approaches: DOA (traditional teaching, allowing the students to use only a pocket calculator), DOA plus LAB (traditional teaching and practice using Microsoft Excel in a computer lab) and DOA plus LAB plus CL (teaching and lab activities based on collaborative strategies) (Brunelli, Galmacci, Gattuso & Pannone, 2000).

Teachers were divided in three groups, depending on the strategy chosen, and the training consisted of three levels: a first course for the DOA approach (20 hours), common for all the groups; a second course on lab activities (12 hours), attended by the second and third group; a course on the CL basic theory and on practical organization of cooperative groups for the last teachers' group (8 hours). During the first training period the pedagogues monitored all the teachers, by means of group interviews, to verify their attitudes and their reactions.

The experiment in the classrooms started at the end of March 2000 and lasted approximately 20 hours, spanned over two months (2 hours more for DOA+LAB and DOA+LAB+CL because of the heavier class organization required). The data collected during the experiment consist of information on the teachers' background and experience, students' scores in mathematics recorded in the first half of the year, and results of three tests. The first test, supplied just before the beginning of the experiment, was intended to verify whether students were able to understand the meaning of some data from a survey published on a newspaper; the second and the third (supplied after the first half and at the end of the experimental period) were aimed to assess the students' knowledge on the various statistical topics.

It is impossible to present here all the details of the analysis carried out on the data collected during the experiment (see Brunelli & Gattuso, 2000; Gattuso & Pannone, 2000; Galmacci & Scrucca, 2000) then we shall only synthesize the most relevant facts emerged. Even though the data require deeper and deeper analysis because of the complexity of the phenomena involved and the number of sub-experimental factors, a first clear image of the results (Galmacci & Scrucca, 2000) can be summarized as follows:

- DOA plus LAB gave generally the best results: students seem to reach a better level of knowledge, ability and criticism
- Cooperative Learning, compared to DOA, made no significant improvement in the students' learning process
- Effects due to the kind of school, to the region and to the teacher are always evident and need further investigations
- Most students with low scores in mathematics received higher scores in the two main tests (second and third) and rediscovered interests toward the discipline (a few teachers, however, have signalled that the best students got bored with statistics because they was fascinated by the more theoretical and abstract aspects of mathematics).

These results surprised most of us for different reasons, mainly for the Cooperative Learning behaviour. Trying to justify this fact, from the analysis of teachers' diaries we deduced that the class organization implied many logistic problems and, consequently, lot of wasted time (even though students were enthusiastic). This fact has also been confirmed by teachers during the meetings organized after the experimentation. Perhaps, due to the very innovative approach for Italian teachers, the Cooperative Learning training should have been longer then we planned. However, teachers' reaction has been positive and some of them are going to adopt this model for the whole mathematics course and not only for the statistics module.

CONCLUSIONS

Even though the experiment has revealed many important unknown aspects about the effects of different teaching strategies, in our opinion there are more relevant results that must be taken into account. First of all, the DOA approach has given rise to a very large interest both in teachers and in students, at every school level. Secondly, the material set up for the teachers' training and for teaching units can be considered a good basis for new textbooks that can present

statistics in a correct and interesting way both for students and teachers who, in Italy, generally have never studied statistics at the University or have only attended highly theoretical courses on mathematical statistics. Finally we hope that this study opened a path for favouring the diffusion of statistics culture among teachers now that they have been in touch with different and hopefully more effective teaching approaches.

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