New Strategies for Teaching Statistics at School*

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1. Introduction

In the international scientific community, because of the relevance that the activities of collecting, representing and processing data have taken over in contemporary society, and in consideration of the growing use of statistical methods in making predictions, there is now general agreement on the idea that the teaching of statistics should be given a broader scope.

The idea that the teaching of statistics should emphasise the understanding of statistical concepts and methods, and also encourage the students to acquire awareness of how important it is to be able to assess the mass of statistical information they come across every day has a similar consensus. The achievement of these aims is facilitated only if students, in their learning experience, are asked to handle concrete problems based on real settings. In that respect, a relevant contribution has been given by David Moore (1997), who suggests that "the most effective learning takes place when content, pedagogy and technology reinforce each other in a balanced manner".

This framework, however, rarely finds concrete application in schools, especially in our country. Here the teaching of statistics, besides being marginal and incorporated in the mathematical curriculum, is very often dealt in an abstract and formal way. There is very limited emphasis on the meaning of concepts and even less on the interpretation of the results. Students need to see mathematics and statistics in a correct perspective, and to distinguish the different features of their logic. In particular, it is fundamental to enable learners to appreciate the role of statistical reasoning, which allows them to read and interpret real phenomena with no pretension of giving "exact answers", nevertheless helping them to develop a more objective view of reality.

The teaching experiment in our research aimed at creating a model for statistics introductory courses based on an approach uncommon in Italy, which we shall refer to as DOA (Data Oriented Approach). The DOA approach is based on the hypothesis that working with real data reflecting a real-life phenomenon favours a better learning of statistical methods and develops students' interests, as they are personally involved in the collection and interpretation of data. To verify the validity of this model and to identify the most suitable strategies for its implementation, we were able to rely on the willingness of the teachers involved in the study to experiment with different types of course management.

The research was carried out in the four CIRDIS[1] units and involved 145 teachers and 2,129 pupils from primary schools (age 6-10), 86 teachers and 1514 pupils from lower secondary school (age 13-14) and 107 teachers and 2500 pupils from secondary school.

[1]CIRDIS is an Inter-University Centre of Research for the Teaching of Statistical Disciplines that includes the Universities of Rome, Padua, Perugia and Palermo.

In the first year the research team identified the statistical content on which the experimentation would be carried out at the three school levels. It was agreed to introduce basic contents apt to promote the setting up and development of statistical reasoning in a variety of concrete situations. Subsequently, training programmes were developed to prepare all the teachers to use the experimental materials. The teachers assigned to the experimental groups in which particular pedagogical models would be implemented all received a supplementary training on the approach chosen.

In the second year, the work focused on the experimentation in schools and the assessment of the results obtained. Experimentation was carried out in all classes at the same period, from March to May of the school year 1999-2000. The students were first administered preliminary tests to assess whether they possessed the prerequisite knowledge and abilities. During and at the end of the experimentation, assessments were carried out through interviews, questionnaires and achievement tests.

2. The experiment at primary school

Pupils of primary schools need to acquire skills to describe and interpret the world around them. For that, they are encouraged to carry out projects in different subjects that often require some data handling and graphical representation, but they are often not aware that all these activities should be in fact named *Statistics*. In other research it has been observed that, while pupils are able to perform some statistical calculations, they don' t have the ability to inspect them critically (Perelli D' Argenzio *et al.*, 1998). This suggests that teaching should be oriented to construct concept nets, in order to avoid learning notions separately without any connections. To verify this hypothesis, the experimentation proposed teaching units for three age levels (6-7 years, 8-9 years, 10 years), all based on DOA, to be implemented accordingly to two distinct teaching models: the traditional teaching method, and the pedagogical model aimed at a connected understanding of concepts via the construction of conceptual maps. Many ideas of the teaching units derive from Pereira and Dunkels (1991) and Dunkels (1999). 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 only slightly better than those following the concept maps teaching. On the other hand, the analysis of the interviews revealed interesting changes in the ability to make connections between common language terms and statistical terms. (Rigatti Luchini *et al*., 2000). 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.

3. The experiment at secondary school

As far as lower and upper secondary school were concerned, the research group designed the contents, management and assessment methods of a basic statistics course with the aim to help learners achieve the competencies necessary to read and interpret quantitative information, while providing the fundamental statistical terminology and installing the basis to learn to think statistically and to acquire the inductive method. More specifically, the course aimed at developing the following abilities in learners:

- set up a statistical survey in order to learn about a social phenomenon;
- make and analyse statistical tables and graphs;
- calculate and understand the meaning of central tendency measures and of variability measures.

We also wanted them to know the main official statistics and realise their importance in decision-making processes in public and everyday life.

The whole course was organised around a statistical survey to be carried out in class, so as allow the students to work with real data and in a real context and make the concepts involved as concrete as possible following the methodology of professional statisticians. The choice of the topic, *Some Aspects of Everyday Life*, gave the students the opportunity to make comparisons with data from official sources, while collecting data near to their interests, and made it possible to illustrate elementary statistical techniques for the analysis of both quantitative and categorical data. The results showed that the advantages of providing a context, such as a survey, were numerous. Giving the students an opportunity to work on data from official sources, created situations which are rarely found in a traditional course, but which are part of the statistician's everyday life. As the students were directly involved in all phases of a statistical survey, they could consolidate notions and concepts while putting them into practice. It was possible for them to correct wrong interpretations while working and to explore the effectiveness of different techniques to verify some working hypotheses.

For the upper secondary school, some teachers adopted a traditional method, allowing the students to use only a pocket calculator for calculation (DOA group); other teachers took advantage of the computer room and had the students perform the various statistical calculations with Excel (DOA+LAB group); a final group, besides using the computer laboratory, applied the Cooperative Learning pedagogical model (DOA+LAB+CL group). Formal CL is based on collaborative strategies, but it differs from other group-teaching methods in the basic principles that characterise a cooperative group (Johnson, D. W., Johnson, R.T. & Holubec E., 1994).

For the lower secondary school two strategies were chosen, both of which are based on DOA: traditional teaching method and Cooperative Learning.

Various means were created and employed to assess the teachers' training and the students' learning. The amount of data collected is large and, although the results obtained up to now need to be confirmed by a deeper analysis, the most important facts can be summarised as follow:

- Formal Cooperative Learning made no improvement in the learning process of high school students, while the results for Intermediate schools show that sometimes CL gives better results than DOA, sometimes worse. To interpret these results, we must take into account, first of all, that classroom management following the formal CL model requires an experience that some teachers could not have completely acquired during the training period; however, we need further investigations to explore this aspect in greater depth.
- High school students who attended modules with Lab activities seemed to reach a better level of knowledge and ability.
- The teachers were generally enthusiastic about the experience and recognised that the experiment in itself has revealed more effective training they could have had in statistics, and the students (mainly those who had problems with the more theoretical parts of mathematics) seem to have rediscovered some interest in that discipline.

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Abstract

Ce texte présente une recherche menée pendant deux ans sur une grande échelle dans cinq régions italiennes dans des écoles élémentaires, secondaires de premier et deuxième cycles. Dans les manuels de statistiques italiens, on insiste plutôt sur les aspects mathématiques sans considérer l'utilité pratique des statistiques et l'interprétation des données. Puisqu'il est très largement reconnu que l'on doit privilégier la compréhension des concepts, un matériel didactique expérimental a été préparé suivant une approche utilisant les données cueillies par les élèves eux-mêmes et nommée DOA, Data Oriented Approach.

Au niveau élémentaire, la recherche proposait des unités didactiques basées sur le DOA mais adaptées à deux différentes méthodes d'enseignement: 1. méthode magistrale traditionnelle et 2. modèle pédagogique visant la compréhension de concepts à travers la construction de schémas conceptuels.

Au niveau secondaire, l'hypothèse testée était que l'enseignement coopératif formel (CL) facilitait la compréhension des statistiques. Au premier cycle on a voulu comparer les résultats obtenus par les élèves travaillant avec l'approche coopérative (DOA+CL) avec ceux qui utilisaient seulement le DOA. Au deuxième cycle où l'utilisation du laboratoire d'informatique est plus répandue, on a mis en place des groupes suivant trois approches: DOA, DOA+LAB, DOA+LAB+CL. L'expérimentation a eu lieu après une formation ad hoc des enseignants et ceci durant le cours de mathématiques à la même période soit mars avril de 2000.

Les différents résultats -selon le niveau scolaire- donnent l'avantage à l'approche DOA, favorisent légèrement l'utilisation de l'ordinateur mais remettent en question les instruments utilisés pour évaluer des approches non-traditionnelles.