AN EXPERIMENT IN TEACHING STATISTICS AT PRIMARY SCHOOL IN ITALY ®

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We report an experiment which involves teaching statistics at compulsory school in Italy (145 primary school teachers and 2130 pupils, 6-10 years old, living in six Italian regions from north to south, giving a total of 132 primary classes were involved) where we evaluate the different efficiency of two different methods of teaching: by Objectives or by Concepts. In this experiment the fact that both these approaches anticipated working with real data reflecting a phenomenon of daily life is of importance. For testing this hypothesis we used multidimensional permutation tests by non parametric combination of dependent tests. Overall the results show that the method by Objectives is better than the method by Concepts.

One of the aims of primary *schools* in Italy is to provide pupils with skills for describing and interpreting the world around them, and such descriptions often require the use of numbers, graphs and diagrams. Pupils are often unaware that all these activities should in fact be termed Statistics. This paper reports an experiment involving teaching statistics at compulsory school in the 1999-2000 school year. 145 primary school teachers and 2130 pupils (6-10 years old) living in six Italian regions from north to south, were involved, giving a total of 132 primary classes.

One specific aim was to evaluate the efficiency of two different methods for teaching statistics: by Objectives (O) and by Concepts (Concept Map Model: CMM). The first approach, (O), is the one traditionally used by teachers in Italy as prescribed by the current ministerial programme. The second, CMM, is more recent and therefore less known and less adopted by teachers in Italy. Other more general aims of the experiment were: to acquire useful elements for a general evaluation, and not only a differential one, of the efficiency of teaching by objectives and by concepts and to introduce children to the idea of Statistics as a method of representation and summary of information (Perelli D'Argenzio, Rigatti Luchini, Moncecchi, & Giambalvo, 2000). The sample populations were:

1. primary I (17 classes, 9 O and 8 CMM) and primary II (24 classes, 17 O and 7 CMM) involving units which aimed to teach the concept of statistical data and their representation;
2. primary III (28 classes, 16 O and 12 CMM) and primary IV (30 classes, 19 O and 11 CMM) with teaching units which included a set of questions for gathering data, and their organization into tables, graphs and stem-and-leaf diagrams;
3. primary V (33 classes, 15 O and 18 CMM) following primaries III and IV, completing the curriculum with calculation of the arithmetic mean.

In this experiment the fact that both these approaches anticipated working with real data reflecting a phenomenon of daily life is of importance. This fact favours structured learning and better learning of statistical methods and also helps to develop pupils' interest, as they are personally involved in the gathering and interpretation of data. The method contributes to the development of critical and explanatory capabilities which, if the formal aspects of the subject are not considered, represents the true difficulty in studying statistics.

In other research we carried out, we observed that although both pupils and teachers do learn some basic notions of Statistics and are able to collect data, represent it, analyse it, calculate averages and so on correctly, they do not have the critical capacities necessary to interpret them correctly (Perelli D'Argenzio, Luchini, & Moncecchi, 1998). In this experiment on primaries one to three the problem of representation was our priority. The representation was carried out in four main phases: 1. *Generation* of micro-data from pupils; 2. *collection* in a disorderly way; 3. *representation* in an arbitrary way; 4. after class discussion, *drawing of pictograms*.

The teachers involved in the trial had in-service training for 32 hours, with the following contents: i) basic concepts of statistics: handling data, data collection, stem-and-leaf plots, representation of tables and graphs, means and elementary concepts of variability; simple methods of critical data analysis, how to inspect data to obtain true information, and how to perceive the validity and meaning of data averages; ii) elements of educational psychology associated with the contents of teaching statistics at primary school; iii) the foundations of a new strategy, the Concept Map Model: concept map, semi-structured class interview, concept net.

Teachers were given teaching units to follow in the classroom: i) the left side of the material contained the unit for pupils; ii) the right side contained suggestions for teachers, possible teaching problems arising at that point, and possible variations of tasks. The teaching units and evaluation tests were prepared for five levels, one for each year. It was at this point that pupils managed to draw block graphs without using numbers or proportionality. At the end of the teaching units, all pupils were given a set of questions, the same set for all classes of the same year. The statistic unit of this trial was a single primary class. The variable *effect of trial* was the total number of pupils in the class who answered correctly. Questions dealt with material (statistical series, graphs, etc.) produced by the pupils themselves.

There were two sub-trial factors: i) experimental teaching S either extensive (E) carried out for a period of two months, or intensive (I) for a period of two weeks; ii) lesson organisation T either lessons were organised over the week, normal time (NT) every morning and two afternoons a week or full time (FT) every day, morning and afternoon, Monday to Friday (or in any case in a more concentrated manner than in NT). The teachers teaching pupils in primary I (8 E the total number of pupils involved in the two teaching methods were 50 O and 85 CMM, hereafter shown by [../..] and 10 I [98/57]; NT 10 [29/88], A 7 [119/54]) and primary II (13 E [164/68], 11 I [150/51]; NT 17 [276/33], A 7 [38/86]) asked their pupils the following questions regarding a diagram which the pupils themselves had made (only the first two questions for primary I): Q1. How many children prefer the bear? Q2. Which animal do most children like best? Q3. Is there one animal which is liked more than another one? Q4. How many children prefer the bear to the horse?

Teachers showed a graph to pupils in primaries III (11 I [145/88], 17 E [99/118]; 16 NT [166/141] and 12 FT [78/65]), IV (17 I [151/91], 13 E [177/103]; 19 NT [143/64] and 11 FT [185/130]), and V (18 E [162/163], 15 I [128/150]; 22 NT [239/171 and 11 FT [51/142]), and said to them: "In an elementary class in another school, the children were curious about something else. They asked in which season most of them had been born". The aim of this check was to detect the acquisition of the capacity to obtain the highest number of data from a graph. The questions were: Q1. How many children in that class were born in autumn? Q2. In which season were most children born? Q3. Were more children born in spring or in winter? If more were born in spring, how many more? Q4. How many children were there in that class? Q5. Make up a table representing the same situation as that shown in the diagram (ideogram).

Information could be obtained directly by counting (Q1 and Q2) or by comparing and subtracting (Q 3). Q4 checked pupils' capacity to understand that the number of children in the class (population number) is given by the sum of those born in both seasons (since no child can be born in more than one season). Q5 checked the capacity to understand that, according to given information, there are no elements allowing a single answer (table). The statistical analysis used for hypothesis testing in this paper was carried out using multivariate permutation tests by using Nonparametric Combination method (NPC; Pesarin, 2001).

The NPC was applied to the responses to single questions, considering classes and teaching method stratified by the two sub-trial factors S and T separately, since their cross-stratification led to analysis on very low or nil numbers of classes. The software used was NPC Test 2.0 (Methodologica srl, 2001). The obtained p-values are shown in Tables 1 and 2 for each partial, combined and overall hypothesis O > CMM (with $\alpha = 0.05$). This unidirectional hypothesis was chosen in order to better understand the importance of methodology O, widely used in Italy, compared to the new approaches.

Table 1
Significance Levels of Partial, Combined and Overall Tests, for Hypothesis O > CMM, in Type T (Normal Time or Full Time).

CLASS	T	Q1	Q2	Q3	Q4	Q5	COMB.
I^	NT	0.2264	0.1628	-	-	-	0.2503
	FT	0.5587	1.0000	-	-	-	0.3618
	GLOBAL I^.						0.2924
II^	NT	0.9106	0.9741	0.8598	0.9528	-	0.9562
	FT	1.0000	0.2267	0.2702	**0.0001**	-	**0.0019**
	GLOBAL II^						**0.0114**
III^	NT	0.0801	0.4603	0.0533	**0.0120**	**0.0001**	**0.0013**
	FT	0.2972	0.1293	**0.0020**	0.3671	0.2853	**0.0339**
	GLOBAL III^						**0.0003**
IV^	NT	0.9710	1.0000	0.9999	0.8652	1.0000	0.9951
	FT	1.0000	0.9707	0.8237	0.5229	**0.0203**	0.2085
	GLOBAL IV^						0.5376
V^	NT	0.9026	0.9955	0.8079	0.9986	**0.0001**	**0.0447**
	FT	0.0569	0.3933	0.3895	**0.0112**	0.9348	0.0536
	GLOBAL V^						**0.0165**
OVERALL							**0.0001**

Table 2
Significance Levels of Partial, Combined and Overall Tests, for Hypothesis O > CMM, in Type S (Intensive or Extensive).

CLASS	S	Q1	Q2	Q3	Q4	Q5	COMB.
I^	I	0.1748	0.7482	-	-	-	0.2900
	E	0.4379	0.9482	-	-	-	0.5508
	GLOBAL I^.						0.4280
II^	I	0.7334	0.7449	0.3332	0.0992	-	0.2174
	E	0.7111	0.7897	0.5131	0.0543	-	0.1205
	GLOBAL II^						0.1189
III^	I	0.4626	0.2682	**0.0212**	0.2889	0.0503	0.0561
	E	**0.0441**	0.4177	**0.0200**	**0.0497**	**0.0003**	**0.0015**
	GLOBAL III^						**0.0010**
IV^	I	0.8591	1.0000	0.3922	0.4683	**0.0001**	**0.0037**
	E	1.0000	0.9813	1.0000	0.8617	1.0000	0.9978
	GLOBAL IV^						**0.0231**
V^	I	0.4275	0.8054	0.8168	0.8536	0.2325	0.5586
	E	0.6901	1.0000	0.1067	0.6545	**0.0006**	**0.0197**
	GLOBAL V^						0.0626
OVERALL							**0.0003**

In both analyses, the overall test gives results which are highly significant confirming the hypothesis that O appears to be better than CMM, independently of some albeit important stratification variables. With reference to the overall tests within each class, it is worth noting that they may be significant, even if one of the two combined tests within each stratum is not significant. In particular, when the stratification variable is T, overall tests for primaries I and IV are not significant. When the stratification variable is S, overall tests for primaries I and II are also not significant and the overall test for primary V is significant only at 7% alpha-level.

This behaviour of the two global tests is justified by the fact that the NPC methodology takes both the dependence among variables Q1, ..., Q5 within each stratum and the different achieved significance levels of overall tests in each stratum into account. This allows the researcher to obtain a global test which completely uses all information gathered from the data. Hence, for a clear interpretation of results we suggest the reader starts by considering each global test and then continues by identifying which stratum, at each step of the analysis, has more or less contributed to the overall significance (step-down interpretation).

Detailed examination of the possible reasons for this result would be interesting but would take up too much space. However, note that primary I was the only class in which there were no significant differences between the two teaching modes. Questions given to lower years did not require calculations so the differences between the two methods were not so evident. Moreover, for the lower years approach O is not yet consolidated such that it conditions the learning of the children.

The differential effect of the two approaches was probably not, therefore, evident. The higher elementary classes, particularly primary III, are more sensitive to the effect between O and CMM. The significance levels of Q5 ("Make up a table representing the same situation as that shown in the diagram") in which critical and creative skills are particularly required, indicate the systematic superiority of O, which focuses on the objective problem and not only on technical rules. The significant statistical differences proved to be more frequent in higher elementary classes where the approach to student's learning (O) is consolidated, so it may be normal to register some differences in favour of O.

Considering that O, compared with CMM, gives priority to the role of teacher over that of student, we can understand the more widespread significant differences (showing O to be better than CMM) recorded in FT compared with NT. FT predisposes children to learning depending greatly on the teacher given that they carry out all their activities with the assistance and under the direct guidance of the teacher, and not alone at home as generally happens with NT pupils.

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