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COMPARATIVE EVALUATION OF LOWER-SECONDARY PHYSICS TEXTBOOKS: THE ROLE OF SCIENCE EDUCATION

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Abstract: We examined in actual school practice the effectiveness of an experimental non-standard introductory book to physical science (physics and chemistry) for the seventh grade (first grade of lower secondary school in Greece). The book has been written by science-education researchers, on the basis of principles of science education. In particular, we compared the performance in a relevant test of an experimental group of students (N_1 = 50) who were taught two physics lessons (on the 'force' and on the 'weight of a body') from the above book, with the performance in the same test of a control group of students (N_2 = 50). who were taught the same topics from the standard eighth-grade physics school book. The study was carried out in four eighth-grade classes of two urban lower-secondary Greek schools. The statistical analysis showed that the non-standard book assisted students more in understanding the taught science concepts. However, due to the marginally small sample size and the very limited number of taught topics, the finding should be considered as a preliminary one.

Keywords: physics textbooks, evaluation of textbooks, science education, force, weight

BACKGROUND AND FRAMEWORK

Teaching can be considered a special form of communication and interpersonal relations between the teacher and the students. The role of textbook is crucial in the teaching process. It ensures this communication and contributes more to the growth of interpersonal relations in the classroom than other teaching tools, such as transparencies, experiments, video, PC, etc. (Armbruster & Anderson, 1991).

The evaluation of textbooks is considered as a necessary and sufficient condition for the upgrading of the provided quality of teaching. However, even though the textbook remains the most important teaching tool, it has not gained its proper place either in the relative research literature or in the educational discussions (Bandura, 1986). On the other hand, the results from relative work (Costa et al., 2000) indicate a limited knowledge on the part of the secondary school teachers about the findings of educational research.

Rationale and Purpose

According to the implications of science education research, modern pedagogy should encourage: (a) the active and constructivist teaching and learning; (b) meaningful and conceptual understanding; (c) the development in students of practical abilities; (c) the connection of science with everyday life; (d) a spiral curriculum; (e) the cultivation of higher-order cognitive skills, such as critical thinking. In principle, the application of such instructional methodologies is primarily the job and responsibility of the teacher, and not so much of the textbook. However, to aid the teacher in this job, and considering the limited awarenees of educational research by secondary school teachers (Costa et al., 2000), two of the authors of this article, who are active researchers in science education, decided to prepare the experimental material for this programme in the form of a complete textbook, containing experiments, theory, questions, and problems (Tsaparlis & Kampourakis, 2003).

To our knowledge there is only one international physics book that is based on the learning-by-inquiry model, namely the American textbook "*Physics by Inquiry*", written by L.C. McDermott and her physics education group at the University of Washington (McDermott, 1996). However, we had not consulted and threfore not followed this textbook in writing our own textbook. Our book is entitled "Introduction to physical science" (physics and chemistry) for the 7th Grade" (first grade of lower secondary school in Greece), and is based on principles of science education. Table 1 provides ten basic principles that were adopted in writing the textbook (for details see Tsaparlis & Kampourakis, 2000). The book was written, tested, and evaluated some years ago in the context of the project SEPPE of the Greek Pedagogic Institute. The reader can see an example lesson ("Chemical reactions in aqueous solutions", translated from Greek into English by the first author) in the Supplementary Information/Part 3, to a paper by Tsaparlis et al. (2010) or directly at the following web address:

http://www.rsc.org/suppdata/rp/c0/c005354f/c005354fesi.pdf

In this work, we compare the above book (henceforth called 'experimental book" (EB) against the standard lower-secondary school physics textbook for the 8^{th} grade (school book, SB) (Antoniou et al., 2007). At the outset, we must emphasize that by this work we do not intend to check if the one book is superior to the other; after all, we only used selective topics and a particular test; in addition, due to the relatively small sample size and the very limited number of taught topics, the findings should be considered as preliminary.

Table 1: The ten guiding principles in the writing of the textbook.

1. The spiral curriculum.	6. Scientific rigor - correct use of language.
2. Use of experiments, especially experiments that will be carried out by groups of pupils.	7. Connection of science with everyday life and applications - Development of environmental conscience.
3. Focus on meaningful learning - discouragement of rote learning.	8. Active and inquiry forms of learning.
4. Emphasis on simplicity of phenomena and concepts - priority given to concrete examples – delay of treatment of the abstract concepts of molecules and atoms.	9. Taking into account of students' alternative ideas and misconceptions (constructivist teaching).
5. Delay of representations with chemical formulae and equations.	10. Contribution to students' cognitive development, as well as encouragement of critical thinking.

METHOD

Two Greek urban schools participated in the study (N_1 = 50 N_2 = 50). In each school, the natural class physics teacher taught two lessons (on the 'force' and on the 'weight of a body') from the EB to an intact school class (experimental class, EC); the same teacher taught the same topics from the SB to a different intact class of the same school (control class, CC). The EC and CC were about equivalent, as advised by the class teacher, and as checked by students' average achievement in the first-term physics test. After the teaching, the students of both classes in each school were given the same test for the same period of time (about 20 minutes). Students' answers were graded by the second author. The physics test is shown in the appendix, and consists of three questions. Questions 1 and 2 were taken from the EB (but had been removed from the students' text), while Question 3 was taken from the SB. All questions were demanding and were selected because they tested both for knowledge and conceptual understanding. The small number of questions was directed by the fact that the teachers had only a limited time (20 minutes) to administer the test, because of limited overall available instructional time.

Internal consistency of the test was checked by calculating Cronbach's alpha coefficient. The alpha values were 0.658 for the SB, 0.710 for the EB, and 0.702 for the total student sample. Values form 0.6 to 0.7 are assumed as showing moderate internal consistency, while values higher than 0.7 show higher consistency (Cortina, 1993).

Reliability of the marking was checked by having three experienced teachers first agreeing on a marking scheme and then each one of them marking 15 randomly selected papers. The non-parametric *Spearman* rho correlation coefficient gave values ranging from 0.852 to 0.972. The 15 papers were also marked independently by the researcher who marked all the papers. The correlation coefficient between the researcher's marking and the average marks of the three other markers ranged from 0.849 to 0.983.

Normality of the distributions was checked by means of the Kolmogorov-Smirnov test. It was found that normality was not followed when taking separately each question, but it was followed when taking all questions together. As a consequence, for the comparison of the achievement in all three questions we used the student *t*-test, while for the comparisons of the achievement in each separate question we used the Mann-Whitney non-parametric test.

All statistical calculations were made by using SSSP.

RESULTS

Figure 1 is a box-and-whiskers plot of student performance per question and the average mark of the three questions for the control and the experimental classes. Every box depicts the range of the 50% of middle marks, leaving out the top and bottom 25%. The horizontal line inside a box shows the median. The whiskers show the highest and lowest mark.

Table 2 has the average marks and the corresponding standard deviations for the four classes, the three questions and the average of achievement in the three questions. For question 1 there is a 26.4% difference in favor of the experimental group. For question 2 this difference is only 2.2%, while for question 3 it is 6.8%. Taking the average of the three questions, the experimental group is superior by 11.8%. For the comparison of achievement in the totality of the three questions, the student *t*-test assumed the value of 2.691 ($p = 0.008$), by using both the hypothesis of equal and unequal variance (Table 3). For the comparisons of the achievement in each separate question, the non-parametric Mann-Whitney test gave Z-values equal to 3.586 for question 1 ($p < 0.01$), 0.764 for question 2 ($p > 0.10$), and 3.082 for

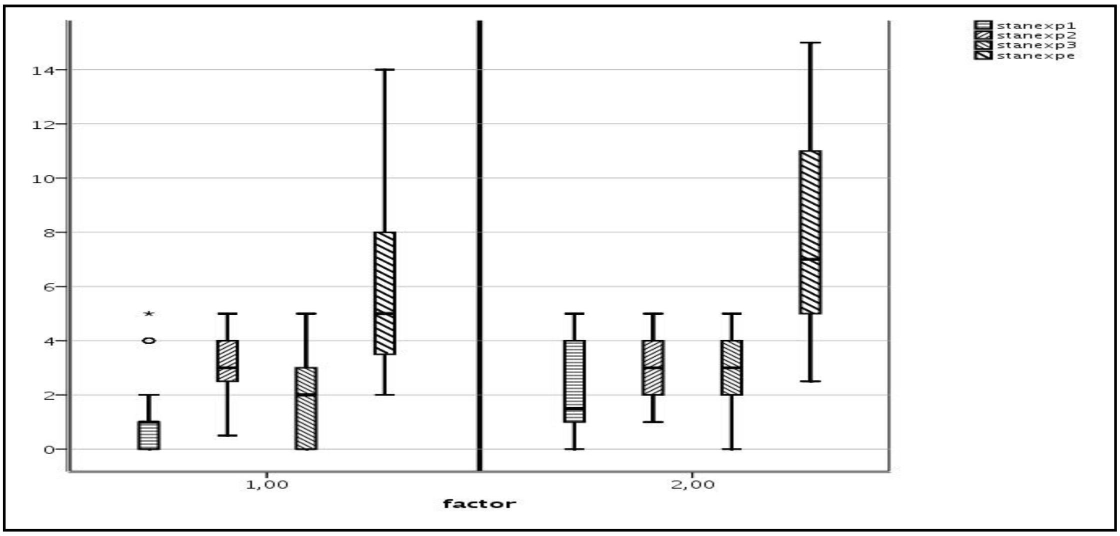

Figure 1. Box-and-whiskers plot of student performance per question and the average mark of the three questions for the control (left-hand side) and the experimental (right hand side) groups.

Table 2: Student achievement per class and per question (mean mark and standards deviations in parentheses (maximum 100). (EC: experimental class; CC: control class)

Class	*Question 1*	*Question 2*	*Question 3*	*Average of three questions*
EC1 (N=25)	40.0 (39.2)	68.0 (24.0)	41.6 (35.6)	49.9(25.9)
EC2 (N=25)	52.8 (37.0)	56.4 (22.8)	47.2 (31.6)	52.1 (22,0)
Total ECs (N=50)	**46.4 (38.2)**	**62.2 (23.8)**	**44.4 (33.4)**	**51.0 (3.60)**
CC1 (N=26)	13.0 (21.8)	65.0 (19.8)	42.4 (30.6)	40.1 (18.2)
CC2 (N=24)	27.6 (32.2)	54.6 (21.8)	32.6 (31.6)	38.2 (21.3)
Total CCs (N=50)	**20.0 (28.0)**	**60.0 (21.2)**	**37.6 (31.2)**	**39.2 (19.6)**

question 3 ($p < 0.01$) (Table 4). In questions 1 and 3, the differences are statistically significant in favor of the experimental classes at the 1% significance level (s.l.). In question 2, the difference is not significant. For the average of the three questions, the difference is significant at the 1% s.l.

DISCUSSION AND IMPLICATIONS

Question 2 asked students to just draw vectors for the exerted forces, but did not require explanations. On the contrary, questions 1 and 3 asked students to explain their answers, hence they were more demanding. This must have contributed to the considerably higher average student marks in question 2.

Table 3: Comparison of performances for the average of the three questions of the experimental and the control group ($N_1 = 50$, $N_2 = 50$) by means of the t statistic.

	Levene test for equality of variances		*t-statistic*		
	F	*Sign. level*	*t*	*d.f.*	*Sign. level*
Hypothesis of equal variances	3.945	0.050	2.691	98.00	0.008
Hypothesis of unequal variances			2.691	94.15	0.008

Table 4: Non-parametric Mann-Whitney test for the separate questions.

	Question 1	Question 2	Question 3
Mann-Whitney U	750.5	1207	811
Z	-3,586	-0,301	-3,082
Asymptotic significance level	0,000	0,764	0,002
Statistical significance	p<0,010 (S)	p>0,10 (NS)	p<0,01(S)

Question 1 had an added problem: from the placement of the three boys in the picture many students made the interpretation that the one boy on the right-hand side was pulling against the force of the two other boys. This is supported by the analysis of interviews taken by a number of students.

In the average of the three questions, there is statistically significant superiority of the experimental classes at the 1% significance level. We conclude that the approach to the concepts of force and weight by the experimental book helped students of the experimental classes more than the approach of the school book.

Finally, we must point out a number of limitations of this study. We only used selective topics and a particular test. Also, due to the relatively small sample size and the very limited number of taught topics, the findings should be considered as preliminary ones. Further study is needed, with more topics, more schools, and more teachers. In any case, we must emphasize that we do not claim by any means that the experimental book (of which authors are two of the authors of this article) is superior to the school physics book for the eighth grade. The authors of the school book are certainly capable and enthusiastic teachers and authors and among them are teachers who have studied physics education. In addition, the experimental group was written with a certain approach which has apparently affected the choice of the particular questions used in this study. If we had used a different test the outcome could have been different. We call the readers therefore to take the above limitations into account in interpreting the findings of this study. Further research is needed, which would include more lessons, taught by many teachers and in many schools.

In conclusion, the current aims of science teaching in secondary schools can be served better by textbooks that employ methods and approaches that are supported by the findings of science education research. This requires the use of a multitude of methods and approaches. The experimental book that was tested in this study has adopted such an approach and provided evidence that supports the claim that this book contributed to better achievement in the studied topic and test.

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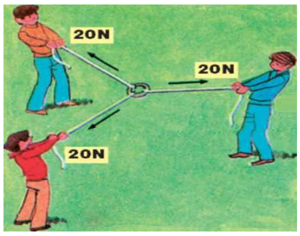
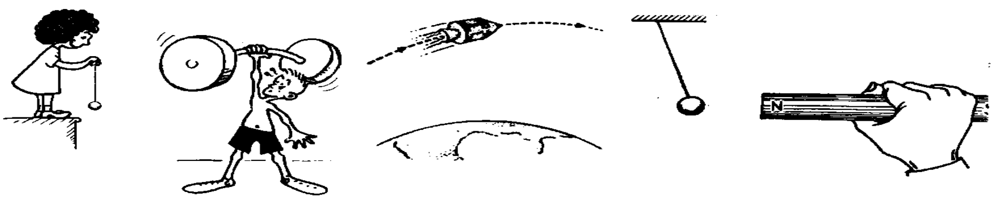
APPENDIX: THE TEST

1. In the figure, each child exerts the same in size force (20 N) on the rope he/she pulls. From the physics point view, are the three forces equal? Explain your answer.



2. In the following pictures, draw the vectors of the forces exerted by: I. The girl's hand on the string. II. The weight-lifter on the weights. III. The earth on the satellite. IV. The magnet on the iron sphere.



3. A schoolmate of yours has this opinion: "A material body has weight when it is on the earth's surface, but it has not weight when it is on the moon's surface". Do you agree? Explain your answer.