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PHYSICS LAB, CRITICAL THINKING AND GENDER DIFFERENCES

B. Mitrevski and O. Zajkov

Institute of Physics, Faculty of Natural Sciences and Mathematics, Gazi Baba bb, 1000 Skopje, Republic of Macedonia

Abstract: This paper deals with the relationship between teaching methods and techniques on one hand and critical thinking on the other hand, with special emphasis on laboratory method and practical work in teaching physics. Classroom lecture with memorizing facts and recall information does not develop critical thinking. But, is the laboratory practice appropriate method in terms of fostering critical thinking? Statistical analysis based on pretest and posttest results show that it is not effective method of teaching critical thinking skills. Additionally, some statistical inferences were made for further insights. Using t test we found no significant difference between male and female students.

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1. INTRODUCTION

This article examines the effectiveness of one non traditional teaching method to stimulate secondary school students in critical thinking (CT). The main question this paper will seek to answer is: "Is physics lab and practical work effective teaching method for stimulating secondary school students' CT skills?" The research study is based on the assumptions that lecture method, as a traditional form of teaching is not appropriate for stimulating and development of students' CT. Along with effectiveness of the teaching method we examined gender differences in achievement on CT test.

Critical thinking

In recent years, especially in the last two decade of 20^{th} century, educational community has evidenced an increased recognition of the importance of CT. Although concerns about deficiency of higher-level thinking skills among students were raised in the 1970s, educators viewed the 1980s as a CT movement due to the increased attention to thinking skills [1]. CT has been identified as key component of education in recent years.

CT is complex mental activity that requires higher levels of cognitive skills in problem solving, decision making and drawing conclusions. Literature reviews of definitions of CT reveal that definitions of this concept vary. According to this, there is no universally accepted unique definition of CT. Sometimes authors suggest that it is better not to be defined, but

explained by its essential components and features, dimensions, and characteristics as how CT experts have done. In this way a well-cultivated critical thinker [2]:

- Raises vital questions and problems, formulating them clearly and precisely;
- Gathers and assesses relevant information, using abstract ideas to interpret it effectively;
- Comes to well-reasoned conclusions and solutions, testing them against relevant criteria and standards;
- Thinks open-mindedly within alternative systems of thought, recognizing and assessing, as need be, their assumptions, implications, and practical consequences;
- Communicates effectively with others in figuring out solution to complex problems.

When CT is defined in terms of abilities, it seems there are some abilities that would appear to be independent, such as: ability to apply principles, ability to interpret data and abilities associated with the nature of proof [3].

Gender difference

People struggle for freedom and equality. Boys and girls spend a lot of time together in school during their formal education. Gender differences in science have been discussed for years. These differences, if any, can be grouped into two main categories: differences in science ability and differences in attitude towards science.

Findings from TIMSS showed that boys had significantly higher mean science achievement than girls at eighth grade internationally and in many countries. It is not a rule because national trends indicate mixed results regard to the gender difference in science achievement. There are major gender differences in some countries and fewer gender differences in others.

For example, TIMSS 1999 showed no statistically significant gender difference (or no any gender difference) in science achievement among Macedonian eighth grade students [4]. Four years later (TIMSS 2003) another generation eighth grade student from the Republic of Macedonia showed statistically significant gender difference in science achievement. Although on average, across most of the countries, boys outperformed girls at the eighth grade, gender difference of Macedonian students favored girls [5].

Graybill found evidence of a gender difference in problem-solving tasks, where girls lagged behind boys in the development of logical thinking ability as defined by Piaget and Inhelder [6]. The differences start to show around the age of 11 years. A moderate correlation has been found between positive attitudes toward science and higher achievement in science [7]. Anyway, it seems the issue of why boys perform better than girls in science or why women do not select science as a career is complex and very controversial.

2. METHODOLOGY

A parallel-group design was used in this study. Experiment with control $(N_C = 80)$ and experimental group $(N_E = 83)$ was performed to scrutinize the possibility of stimulating CT skills with this teaching method. Sample students were 10th grade, age between 15.8 and 16.6 years.

In order to have an equal control and experimental group (C and E) classes were selected according to the physics marks, overall achievement and the teacher's suggestions.

Lab physics and practical work was used in E during teaching the unit "Electric current". Many practical activities, such as demonstrations, conducting experiments and research activities were performed in E.

Students were pretested and posttested using CT test. The test was developed by the authors. Evaluation process has included checking, revision and modifying the questions using both pilot and focus group methods. This test measures subject specific CT skills in a specific content area-physics. Students were scored on a scale ranging from 0 to 50, with higher scores representing the better achievement. Test reliability was measured using test-retest method. Stability index was calculate on the other group of fifty-one students and calculated value is $r = 0.76$ ($p < 0.01$).

3. RESULTS

After checking the normality of score results frequency distribution (Kolmogorov test), hypothesis of equality of C and E was tested by parametric *t* test. Pretest results were analyzed statistically and the descriptive statistics (minimum, maximum, mode, median, mean and standard deviation s) is shown in Table 1. The final pretest sample included 154 students, 50% of them male and 50% female.

Table 1. Descriptive statistics, pretest (BT_01)

Pretest BT_01									
Group	*N*	male	female	min	max	mode	median	mean ($\overline{X}$)	*s*
C	77	41	36	0	37	4	11	13.65	9.45
E	77	36	41	0	28	9	12	12.40	6.00

Firstly, before making inference normality distribution was tested using Kolmogorov test. Statistical significance was set at $p < 0.05$. Results show that students' score are normally distributed. After that, the pretest scores were analyzed using the two-tailed *t*-test for two independent samples to guarantee the equality of the groups prior to instruction. Calculated

value $t = 0.980$ is less than $t_{\alpha=0.05}(\mathrm{df} = 152) = 1.98$, therefore we accept the null hypothesis $H_0 : \overline{X}_{\mathrm{E}} = \overline{X}_{\mathrm{C}}$. Posttest results are shown in Table 2.

Table 2. Descriptive statistics, posttest (PT_01)

Posttest PT_01									
Group	*N*	male	female	min	max	mode	median	mean ($\overline{X}$)	*s*
C	73	40	33	0	37	24	20	19.08	8.17
E	71	36	35	0	43	32	22	20.99	10.99

As it was expected students' scores on posttest were much better then on the pretest. Although, posttest results of students in E are slightly better than the ones in C, we can see that, there is almost no mean difference between C and E. The data on the graph below show normal distribution of the relative frequencies.

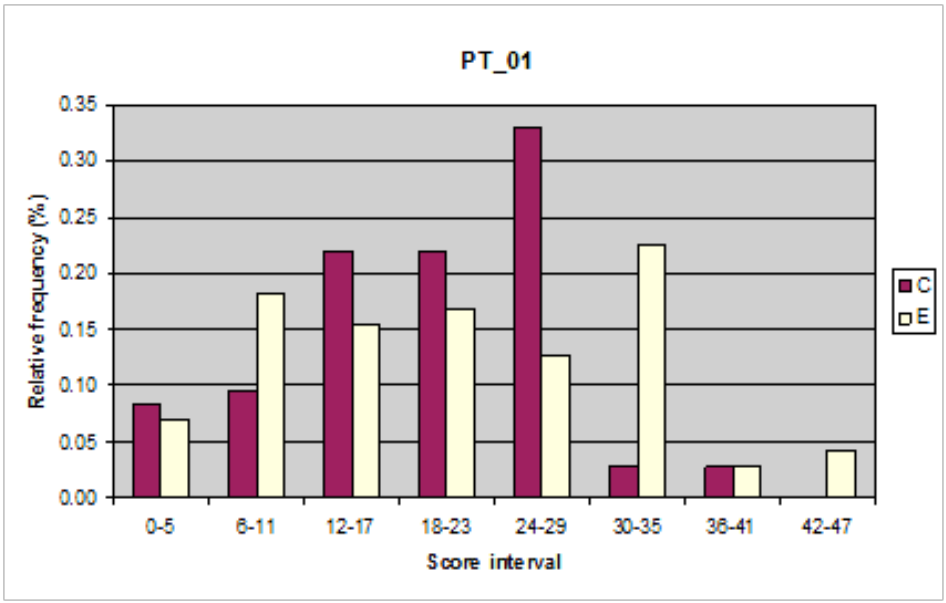

Fig.1: Posttest results frequency distribution.

We used one-tailed *t*-test for measuring the significance of the difference between the means of the two independent samples. Calculated value $t = 1.18$ is less than tabulated value at $p < 0.05$, so there is no statistically significant difference between the means of the groups.

In order to characterize the change between pretest and posttest scores, normalized change c was used. Scatter plot of normalized change versus pretest score (%) is shown in Figure 2. Average value is $\overline{c} = 0.18$ and this number indicates a low normalized change.

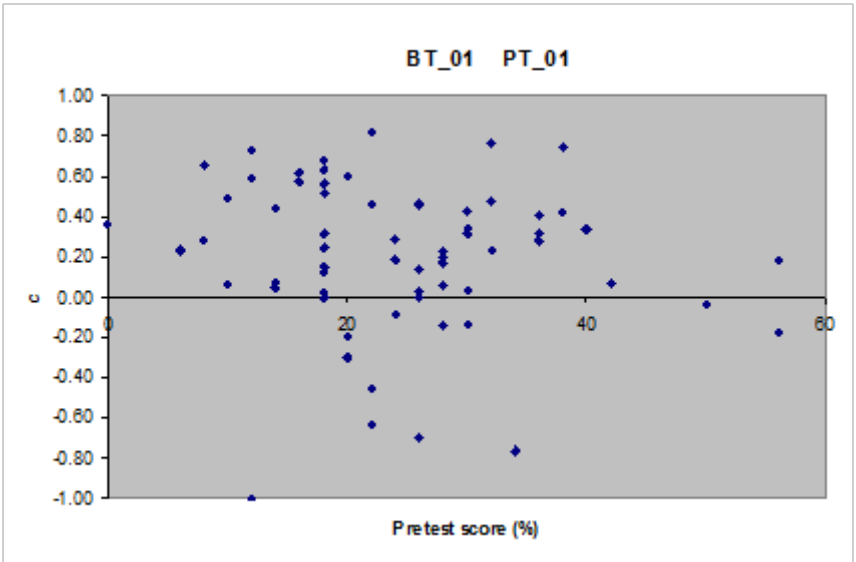

Fig.2: Normalized change.

We also used t test to examine gender difference. It was conducted for both, control and experimental group. Descriptive statistics and t test results are shown in Table 3 and Table 4.

Table 3. Descriptive statistics and t test results, posttest (PT_01)

Control group									
Group	*N*	min	max	mode	median	mean	*s*	*t*	sig.
male	40	4	32	24	18	17.93	8.03	1.33	n.s.
female	33	0	37	24	21	20.48	8.23		

n.s. means no significant

Table 4. Descriptive statistics and t test results, posttest (PT_01)

Experimental group									
Group	*N*	min	max	mode	median	mean	*s*	*t*	sig.
male	36	0	43	6	22.5	20.89	10.92	0.076	n.s.
female	35	4	42	32	20	21.09	11.22		

From the Table 3 and Table 4 one can see that calculated t values of 1.33 and 0.076 are less than the critical value of 1.96 at $p < 0.05$ (two tailed t test). Based on this, the null hypothesis, which claims that there is no statistically significant gender difference, is accepted.

This means that for both, control and experimental group, there is no significant difference between male and female students in their achievement on CT test. Therefore, there is not significant gender difference, no matter which teaching method is used.

3. CONCLUSIONS

The present study compared effectiveness of non traditional versus traditional lecture-based teaching method on students' CT, measured with subject specific CT test. Results show that lab physics and practical work teaching method is not effective in terms of stimulating CT skills, because the data have indicated no statistically significant difference between groups. Also, the findings of the study indicate that the gender difference does not exist in terms of students' achievement on CT test.

Since development of CT skills takes time, further researches are needed to evaluate effectiveness of non traditional teaching methods. Maybe two months of instruction time is too short to have a significant change in students' CT. An additional recommendation for further analysis relates to the research instrument. Sometimes, it is useful and researchers recommend using more than one assessment tool for a comprehensive and valid measurement due to the multidimensional aspects of CT.

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