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DEMONSTRATION IN TEACHING PHYSICS

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Summary – *This paper aims to answer the question if there is a difference in understanding the basic concepts of physics when applying the contemporary and traditional demonstration (an experiment demonstrated by a teacher). The research was carried out on a relevant sample (N=82) of students in the 7th grade of primary school, divided into two experimental groups – demonstration and hypothesis-discussion groups, and a control group (non-demonstration group). The testing process was carried out by using tests created by the author. The test components combine multiple-choice questions and explanation questions.*

The results have shown that, statistically, there is no significant difference between observation and hypothesis-discussion groups in answers (t=0.15, p>0.1) and explanations (t=0.55, p>.01). On the other hand, hypothesis-discussion group has achieved significantly better results in answers (t=2.25, p<.03) and explanations (t=2.05, p<.05) when compared to the control group.

This research has shown that the effect of demonstration makes a significant contribution to general and conceptual understanding of the concepts of physics in cases when students make hypotheses and discuss them, when they create experiments, verify their hypothesis and make conclusions.

Key words*: demonstration, hypothesis, discussion*

INTRODUCTION

Nowadays, most authors (Mikuličić et al., 2003; Crouch, 2004) consider an experiment the basic teaching method in Physics and Sciences. Based on their form, experiments in teaching Physics can be divided into two forms: demonstration and students' experiment (Mikuličić et al., 2003). Demonstration is conducted by a teacher, aiming at defining a problem, confirmation (or refutation) of the previously made hypotheses or gathering of relevant physical data. Normally demonstration is conducted when it requires complex or expensive equipment. A students' experiment has the same aims, but is conducted by students themselves, independently.

In the teaching practice throughout primary schools in Croatia, determined didactically and materially, demonstration is still the predominant teaching method in relation to students' experiment. That is why it is useful to view the way in which demonstration is presented, bearing in mind the division into traditional and contemporary teaching process, which facilitates the understanding of its fundamental role in teaching Physics, but Sciences as well.

In philosophy and methodology of sciences, four educational paradigms have been successively alternating (Park, 2004). Within these paradigms, teaching Physics and experiments within it, has been interpreted in different ways. The rationalists base the methods of science on mathematical deduction, according to which the inevitable consequences are drawn from the most general cognitive truths applying an appropriate method. These consequences help us realize what reality is and what an illusion is. According to this paradigm, human spirit contains a set of privileged ideas and methods which help us draw other ideas. Therefore, for rationalists, experiment and experience are superfluous.

Opposite to the rationalist paradigm, the empirical paradigm focuses on experience based on observation and experiment. The empiricists use the method of induction according to which the individual observation of environment leads to the range of broad generalizations, which again lead to the most general axioms. In that process, experience is not mere observation, susceptible to the tricks of our perception, but is based on systematic observation, comparison and verification (Lelas, Vukelja, 1996).

The science and teaching of Physics in the 19th and the first half of the 20th century was based on the methods of induction and deduction; induction implying observation and experiment, deduction implying the creation of mathematical formalism. In the teaching practice, during the elementary education in sciences, this means conducting experiments exclusively for the purpose of observation and information gathering, followed by the formalization of knowledge. In this process, a student observing an experiment is a passive observer and knowledge recipient, who formalizes the knowledge having witnessed the experiment. This kind of experiment, the sole purpose of which is to observe and note a certain phenomenon is nowadays known as the traditional demonstration.

Constructivism, the contemporary paradigm in Physics teaching was formed in the 1980s, based on the empirical paradigm through CLISP[1] project, using the basic principles in the philosophy of Khun, Pooper and others. Constructivism perceives a student as an active participant and analyst of the teaching process.

[1] CLISP – Children's Learning in Science Project (Park, 2004).

Within this approach, the role of demonstration changes methodologically and philosophically. In the constructivist demonstration a student is included in all ''scientific'' stages and procedures of an experiment. The notion ''scientific'' encompasses all the procedures used by students, and which precede all scientific procedures, such as: observation, detecting, making hypothesis, experiment preparation, information gathering, information analysis, finding solutions and solution verification. An experiment created using such methodology, in which none of the research stages or students' intellectual involvement has been omitted, points to better results in conceptual understanding of physical concepts, in recognition and correction of typical students' misconceptions. (Halloun, Hestenes, 1985; Crouch, 2004).

Therefore, the aim of this research is to precisely determine the difference in general and conceptual knowledge when traditional and contemporary teaching is applied.

THE AIM OF THE RESEARCH

The aim of this research is to determine to what extent the contemporary demonstration based on hypothesis and discussion affects the understanding of basic physical concepts, compared to the traditional demonstration based on observation.

HYPOTHESES

H_0 – there are no differences between experimental groups (OG[2] and HDG[3]) and control group (NDG[4]) in the frequency of correct ''answers'' and ''explanations'' on the Physics test;

H_1 – observation group (OG) achieves statistically and significantly better results in the frequency of correct ''answers'' on the Physics test when compared to control group (NDG);

H_2 – observation group (OG) achieves statistically and significantly better results in the frequency of correct ''explanations'' on the Physics test when compared to control group (NDG);

H_3 – hypothesis-discussion group (HDG) achieves statistically and significantly better results in the frequency of correct ''answers'' on the Physics test when compared to control group (NDG);

[2] OG – observation group (traditional demonstration)

[3] HDG – hypothesis-discussion group

[4] NDG – non-demonstration group (control group)

H_4 – hypothesis-discussion group (HDG) achieves statistically and significantly better results in the frequency of correct ‘’explanations’’ on the Physics test when compared to control group (NDG).

METHODOLOGY

The research included a relevant sample of the 7th grade students (N=82) of a primary school in Zaprešić. This sample encompassed three 7th grades which, using the method of random selection, formed two experimental (OG, HDG) and a control group (NDG). Experimental and control group were equated in all relevant features: number (N_{NDG}=28, N_{OG}=27, N_{HDG}=27), gender (N_F=N_M), age (M=13 years) and education (all students attend the 7th grade of primary school and have identical previous knowledge of Physics). Both experimental and the control groups were included in the experiment within the time span of 4 school weeks (2 periods of Physics a week), during which they were attending lessons on physical concepts such as ‘’internal energy, heat and temperature’’.

Each group participated in demonstration which was conducted using various teaching methods. In observation group, the traditional demonstration was conducted, implemented through the observation-listening approach, which again was based solely on observing the experiment and listening to the teacher’s explanations. The teacher-student communication here was a one-way irreversible process, where a student was a passive observer of the experiment.

Within the methodological framework with hypothesis-discussion group the methodological curriculum was employed. It was based on the fundamental scientific procedures, especially on making hypotheses and discussion. Hypothesis-discussion group conducts demonstration as an element in verifying (not proving) the hypotheses which had been drawn from the discussion.

The results obtained for the two experimental groups were then compared to non-demonstration/control group which had not taken part in demonstration. The control (NDG) group supplemented the experiment by working on the text which described and explained the results of an imaginary experiment.

In order to verify the hypotheses that had been made, a test[5] created by the author was used. The test consists of five components taken from the references (Šindler, Mikuličić, 2005; Mikuličić, Krsnik, 2001) and additionally adapted by the author to meet the criteria of this research. The test components were created as a combination of multiple-choice questions and the explanations of the given statements. All the suggestions for creating the multiple-choice questions were taken into consideration (Hudson, Hudson, 1981; Aubrecht II., Aubrecht, 1983). The metric test characteristics, validity and reliability were checked. The criterion for the test validity verification is the curriculum, which is in co-relation with

[5] The test sample can be seen in the appendix.

the test content. The validity was not precisely checked since it is a very short test solved by most of the students (difficulty coefficient >0.2, discrimination index >0.3).

The content of test components posed identical physical problems, but in different forms, dealt with through demonstration process during the lessons. The students were required to circle one of the offered answers (''answers''), and then to give a detailed explanation of its physical validity. The test evaluation was carried out separately for answers and explanations. The results obtained through the test were measured as frequencies, and each answer and explanation was given a numbered dichotomy variable (0 – incorrect, 1– correct; for answers and explanations separately). The assessment was carried out by two independent graders whose results showed complete agreement (W=1). Since the test results are presented as frequency units, the research statistics was based on proportions, and testing the difference among the proportions was calculated for small independent samples. Statistical and graphical data processing was carried out using the Origin 7.5 program.

RESULTS AND DISCUSSION

Table 1. shows the statistical results of the test for experimental (OG and HDG) and control (NDG) group.

Table 1. Results achieved on Physics test (answers and explanations) for OG, HDG and control (NDG) group

Group	Answers				Explanations		
	N	p	t	P	p	t	P
NDG (k)	28	0.63 ± 0.09	-	-	0.25 ± 0.08	-	-
PG	27	0.65 ± 0.09	0.15	> .01	0.31 ± 0.09	0.55	> .01
PRG	27	0.90 ± 0.06^{+}	2.25	< .03*	0.52 ± 0.09	2.07	< .05*

$^{+}$standard error calculated for normal proportions distribution; *statistically significant (min. level $P<.05$)

In order to test the hypotheses H_1 and H_3 the proportion of occurrence was calculated. The results reveal the identical proportions for observation (OG) and control (NDG) groups. The standard error calculated for the proportions for observation group was relatively high and points to a wider dispersion around the central mean value (OG range; 0.63±0.27), which indicates a significant inconsistency of the results achieved in the explanations component of the test. A wide range of the obtained results is on the level normally achieved on tests in traditional teaching.

The testing of hypothesis H_1 through independent two-way t-test showed that there is no statistically significant difference ($t=0.15$, $P>.01$) between OG and control group in the ''answers'' part of the test, which refutes hypothesis H_1. That corroborates the fact which other authors (Crouch et al., 2004) have also pointed to, that traditional demonstration as a teaching method has no methodological value if it is conducted mainly for the detection of a certain physical phenomenon, leaving out other scientific procedures. On the other hand, HDG group achieved exceptionally good results in the ''answers'' part of the test, which contributes to a highly pronounced calculated proportion of occurrence. Since the proportion of occurrence for HDG is high and the number of respondents small, for the purpose of precise calculation of standard proportion error, a 95% level of reliability was read from a nomogram and is ($0.75 \le p \le 0.95$). An exceptionally high achievement of the HDG in the frequency of correct answers also differs statistically ($t=2.25$, $P<.03$) in comparison to control group. That corroborates hypothesis H_3 about a higher frequency of correct answers of HDG in the ''answers'' component on the multiple choice test. This undoubtedly leads to the conclusion on the methodological necessity of hypothesis and assumption as essential scientific procedures, which account for a significantly better effect with respect to memory and reproduction of the content of Physics. This kind of result is even more paradoxical when it is known that, although not deliberately, the traditional demonstration and traditional teaching insist on cognitive processes of remembering and content presentation.

The second column in Table 1. shows the results students have achieved in the ''explanations'' component on the Physics test. In all groups, the proportions results for explanations are of a lower quantitative value when compared with the answers results. Two facts account for that. Firstly, students who are in transition from a concrete thinking stage to the stage where they are acquiring the skills of thinking formally find it difficult to make abstractions of the relevant concepts and provide a valid physical explanation. Secondly, the test graders insisted on completely accurate explanations, and only such explanations were marked as correct. However, the testing of differences in the arithmetic mean revealed statistically significant differences ($t=2.07$, $P<.05$) in the number of correct explanations between HDG group and NDG group. That corroborates hypothesis H_4. A relatively small t-value of 5% was obtained on the risk level, which was caused by testing the differences on a relatively small number of respondents. Still, this small sample of respondents shows the double proportion of correct explanations in NDG population, which is a relevant result. The range of result distribution for some groups slightly changes ($s_p \approx 0.09$). The results of similar research (Crouch et al., 2004) with a greater number of respondents ($N>150$) point to the similar tendency. On the sample of college students Crouch et al. detected the occurrence proportion of $p=0.3$ for the hypothesis group, with statistical significance on level $P<.04$ and $p=0.32$ for discussion group on level $P<.02$ (control group $p=0.22$). Although the groups and research methodology were not identical, it is evident that there is a correlation between the calculated differences in the arithmetic mean and their statistical significance which is not high, but is still relevant. This comparison has once again corroborated the fact that the elements of hypothesizing and discussion are very important when demonstration is used as a teaching method.

In order to provide a clearer illustration of this research, the results obtained in the research have been analysed graphically. Figure 1 shows a bar graph which gives the normative values of the results the respondents achieved on the ''answers'' test and their explanations. The graph makes it obvious that hypothesis-discussion group was superior to observation group, especially in the area of explanations of physical problems.

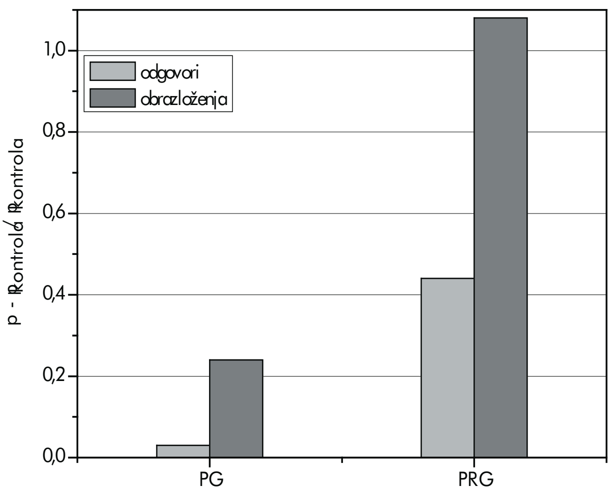

Figure 1. The value of results achieved on 'answers' test and explanations for OG and HDG.

Since experimental groups applied different methodological approaches while conducting demonstration, for the purpose of this research the time spent on each of the activities (making hypotheses, discussion etc.) was measured. The time measured showed to what extent OG and HDG groups were lagging behind in the curriculum when compared to control group. Approximately, OG fell back 1 school period and HDG 3 school periods. Measured in time units, OG spends $\bar{t}$ = 6 min on demonstration, while HDG spends $\bar{t}$ = 18 min. The measured time is not so long if two facts are taken into consideration. Firstly, the student activity, the pace of making and writing hypotheses and quality discussion were all determined by students' cognitive maturity (Šindler, 1990), which takes more time. Secondly, positive results achieved through hypothesis-discussion method have also been supported by other types of research (Crouch, 2004; Hake, 1998).

CONCLUSION

Two basic conclusions can be drawn from this research. Demonstration, as a teaching method in Physics teaching process leads to significantly better results when it follows scientific stages: hypothesis making and discussion, experiment, conclusion. The results imply better general and conceptual understanding of basic physical concepts and measures. On the other hand, these results are extremely low when demonstration is conducted in a traditional manner, in which a student is only a passive observer and knowledge recipient and the sole purpose of an experiment is for students to perceive a certain phenomenon. Therefore, demonstration in the Physics teaching process should help students to: (a) confirm or refute their hypotheses, (b) gather relevant information, (c) draw conclusions, not having just an entertaining lesson which interrupts usually boring topics (Di Stefano, 1996). This research has shown greater efficiency of a modern demonstration compared to a traditional demonstration. Modern demonstration, although slightly more time-consuming, leads to higher achievement and better results.

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APPENDIX

Item test used in the research
1. Hit a thin metal plate with a hammer. Kinetic energy of the hammer transforms into: (a) heat (b) chemical energy of the plate (c) internal energy of the plate (d) temperature Give a detailed explanation of your answer.
2. Close the opening on the bicycle tyre pump with your finger. On your finger you can feel: (a) the pump pressure (b) the pressure of air particles (c) kinetic energy (d) none of the above How do you explain it?
3. After rubbing a mercury thermometer, the temperature it shows is: (a) higher (b) the same as it was before rubbing (c) lower (d) none of the above is correct How do you explain it?
4. We heat an iron ball on the fire. Before heating, we could push the ball through a metal ring. After heating, the ball: (a) can be pushed through the metal ring (b) can't be pushed through the metal ring (c) none of the above is correct Provide a detailed explanation using the particle model!
5. When a body is heated (such as the iron ball), its volume increases. That happens because: (a) the number of particles increases (b) the particles vibrate more so the distance between them increases (c) the volume of the particles increases (d) air enters the space between the particles Explain in detail why you refute of accept the answers above?