# Increasing the attractiveness of school physics: the effects of two different designs of physics learning

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Recibido el 12 de enero de 2012; aceptado el 7 de mayo de 2012

In this research we have used a specially prepared survey in order to assess the relative efficiency of two different designs of students' learning activities, called *Reading, Presenting, and Questioning* (RPQ) and *Experimenting and Discussion* (ED), both with objective to improve students' attitudes towards the attractiveness of school physics. The data of a one-semester-long high-school project indicate that RPQ group (91 students) achived an improvement of +4% in attitudes while the ED group (85 students) got an improvement of +23% as measured by the survey designed specifically for this study. Our results suggest that the ED method is a good model for a significant improvement of students' attitudes towards the attractiveness of school physics, both for girls and boys who study high school physics.

*Keywords:* Active physics learning; students' attitudes toward physics; attractiveness of school physics.

En esta investigación hemos utilizado una encuesta especialmente preparada con el fin de evaluar la eficiencia relativa de dos diseños diferentes de las actividades de aprendizaje de los estudiantes, llamados Leer, Presentar y Questionar (RPQ, por su nombre en inglés) y Experimentar y Discutir (ED), ambos con el objetivo de cambiar positivamente las actitudes de los estudiantes hacia la atractividad de la física escolar. Los datos del proyecto, con un semestre de duración en el nivel de bachillerato, indican que el grupo RPQ (91 alumnos) lograró una mejora del +4% en las actitudes, mientras que el grupo ED (85 estudiantes) obtuvo una mejora del +23%. Estos resultados sugieren que el método ED es un buen modelo para una mejora significativa de las actitudes de los estudiantes hacia la atractividad de la física escolar, tanto para los alumnos y como para las alumnas, quienes estudian la física en el nivel de bachillerato.

*Descriptores:* Aprendizaje active de física; actitudes estudiantiles hacia física; atractividad de la física escolar.

PACS: 01.40.Fk; 01.40.Di; 01.40.gb

## 1. Introduction

In contemporary physics education there is a growing concern about the lack of student interest in physics courses or avoiding choosing physics in colleges. When choosing physics, students primarily consider a strategic value for improvement of their own university career [3]. However Spall and collaborators [1] report that school physics is significantly less popular than biology with British students. Other data indicate that more students choose chemistry and biology over physics in Canada [2].

The general interest in physics-related societal questions should be differentiated from the interest in physics as a school subject [4]. The interest in physics as a school subject is a combination of individual interest in physics, interest in specific physical topics, short-term interest in physical situations deemed interesting [5], and social climate in class during physics classes. The specific combination of these factors which define the interest in physics as a school subject vary from one student to another.

There is a substantial body of literature that examined students attitudes, interests and opinions about science *e.g.* [6-8]. Ormerod and Duckworth [6] claim it is important to develop interest in science already in primary school. Those early scientific experiences can be relevant for future students' long-term interests toward science [6].

Students who have a positive opinion about science, who are fascinated by natural phenomena and who recognize general importance of science or its role in their own future, still do not have to necessairly be interested in physics they are exposed to in classrooms [7].

Many high school students consider study of science irrelevant, difficult and uninteresting [9]. Various researchers [10,11] conclude that the quality of school science classes largely determine student later attitudes towards science. In most countries, data indicate that children come to high schools with interest and a very positive attitude towards science. However, both their attitude and their interest in this respect frequently significantly change, being negatively influenced by the experience in high school science classes, which is particularly noticeable with girls [12].

Furthermore, the literature indicates that students' descriptions of science classes, although different, generally have four characteristics [13]:

- The subject is focused on the facts that are transferred from professional sources (text or teacher) to a relatively passive student;
- The curriculum content is often presented in a decontextualized way which leads many students to experience science as irrelevant and boring;
- Students consider physics and chemistry the most difficult scientific courses, generally more difficult than most school subjects;

- Physics and chemistry play role of subjects that have a primary strategic value of selection and promotion of students' university career.

Most girls prefer to study physics through conversation and cooperative activity, and to work with concrete objects. Boys, however, to a large extent love learning through argumented and individual activities [14]. However, most of the classroom related activities are organized for the studying styles prefered by boys [14]. That is one of the reasons for which it is more likely that girls may be less interested in learning than their male colleagues. Due to the lack of interest, most girls will probably more often learn physics by memorization only [15].

In general, girls' awareness of their pre- and outside-school physics experiences is lower than that of the boys'. Therefore, physics classes may be more relevant for the development of higher interest in physics for girls than they are for boys [4].

Several studies found the correlation between the relatively negative student attitudes towards science and the traditional approach to scientific instruction [16,17]. Traditional approach is characterized by frontal teaching accompanied by the greater amount of information presented to students and by considerable testing. This teaching format creates an environment in which the teachers frequently have just enough time to present information in a summarized form. Many such curricula and programs have, intentionally or not, put emphasis on activites such as memorising, verbal reproduction and the lack of intelectual challenge [18].

A way of solving some of the current physics educational problems may be by modifying existing curricula so to add subjects that awaken students' interest [19]. For example, it would be beneficial to augment standard curricula with topics such as astronomy and history of science since these seem to appeal to both genders [20-24].

The goal of this research was to explore how two different "learning packages"[i], Reading, Presenting, and Questioning (RPQ) and Experimenting and Discussion (ED), affect attractiveness of physics for high school students. At the same time we will study the correlation between the change of attractiveness of school physics for high school students and the level of their scientific reasoning.

## 2. Study Design

In this study, we tried to answer the following research question:

Can two different designs of physics learning, *Reading, Presenting, and Questioning* (RPQ) and *Experimenting and Discussion* (ED), change students' level of interest in physics?

Students' attitudes towards the attractiveness of school physics were measured prior and after the semester in which new learning experiences were obtained. The attitudes were measured by a survey consisting of four statements:

1. For me, physics is the most interesting school subject.
2. The attractiveness of physics is determined by the wideness of applicability of its concepts.
3. The attractiveness of physics is determined by its, frequently surprising experiments.
4. The attractiveness of physics is determined by the elegance of its mathematical formulas.

These statements were formulated based on several sources. The first statement can be found, in a slightly different form, in the VASS (Views About Sciences Survey) [25,26], the second and the fourth are derived from the MPEX (The Maryland Physics Expectations Survey) [25], VASS and CLASS (Colorado Learning Attitudes about Science Survey) [28] surveys, while the third one results from the PEVA (Pedagogical Expectancy Violation Assessment) [29]. It can also be added that some aspects of the second and the third statements are present in the physicist "folk culture", while the third statement is also based on previous students' reactions to similar experiments, known to the first author.

### 2.1. General information about students and curriculum

The study was conducted with 6 classes (natural groups, formed by girls and boys) of senior high school students (17–18 years) in Split (Croatia) during spring semester of 2009. This period is particularly suitable for conducting the project because the students are in the last semester of their high school education and already possess knowledge from different scientific areas as well as attitudes towards them. The total number of students was 176 coming from the grammar high school and the modern languages oriented curriculum. Although these study programmes are language - oriented, the students may decide to attend different courses at university level: from humanities to scientific and technical studies.

In the Republic of Croatia there is no major difference between different college prep high school programs. This way, students are given the opportunity to find their field of greatest interest which often changes in the period of the four high school years. Therefore, the curriculum also includes science subjects - biology, physics, and chemistry - with two lessons per week, throughout the high school education.

The research on effects of non - traditional teaching methods lasted one (spring) semester and was carried out with two groups of students, each group consisting of three physics sections. Both groups studied the topics that were set by the annual syllabus [30]. The main themes were energy spectra, atomic nuclei, elementary particles, evolution of Cosmos and deterministic chaos.

Within the physics curriculum one out of two 45-minute sessions per week can be used for free topic exploration and one is mandatory curriculum. This means that, apart from the topics set by the syllabus, the teacher is allowed to introduce some additional ones that may reflect teacher's and/or students' interests. This free topic time was used for the research. In other words, a total number of 16 forty five - minute sessions (in the period of 16 weeks) were at the disposal for the project. These included 12 sessions for treating the chosen topics and 4 sessions for pre and post assessments. The topics were chosen by "the authors".

The instructor in all classes, throughout the research, was same (the first author) and he made all possible efforts not to affect objectiveness of the results.

### 2.2. The two different pedagogical methods

#### *2.2.1. Reading, Presenting, and Questioning (RPQ)*

RPQ pedagogy was applied to a group of three physics sections (91 students). They were introduced to some of the topics related to the recent scientific discoveries in physics in the following way:

(i) students' autonomous reading/study of popular articles suggested by the teacher–researcher,

(ii) reading/study of on-line resources, some mandatory and some discovered by the students themselves in cyberspace,

(iii) students' presentations of the learning results in Power Point? format,

(iv) students' questioning about unclear elements of reading and peer-presented materials.

The rationale behind this design was derived from successful practices like 'read to learn" [31,32], "present to learn" [33,34], and "question to learn" [35-37].

Two examples were chosen to illustrate the ways in which modern science has gained new knowledge.

1. Large Hadron Collider (LHC) at CERN

- One huge experiment, Compact Muon Solenoid (CMS), was studied in detail along with its scientific potential and technologies developed for that purpose.

2. Wilkinson Microwave Anisotropic Probe (WMAP)

- A detailed analysis was performed of how the experiment was conducted, how data were organized and what were the major findings,

- Mentioning other experiments that confirmed the results of WMAP (*e.g.* Method supernova Ia).

This teaching/learning design also involved breaking down each section into three different teams, with the purpose of encouraging discussion and further analysis of the suggested topics from the field of contemporary physics.

In each section, three teams were formed for the following tasks:

a. presenting the problems and questions that arise from the first topic (LHC),

b. presenting the problems and questions that arise from the second topic (WMAP),

c. critically analyze and evaluate reading materials and question the peers who presented the topic.

The students chose the teams themselves, depending on their interests as well as on the level of proficiency in physics.

The teacher appointed a team leader who was in charge of distributing reference materials and preparing the group for their role in the project and presentation on the given topic, as advised by Slavin [38,39] and Johnson and Johnson [40]. Each team consisted of approximately the same number of students and its size depended on the total number of students in a class (from 8 to 11 students per team).

The final aim was to encourage a discussion among the students' teams which would reveal the cognitive processes, attitudes, and motivation.

This part of the research was initiated by a lecture given by Professor of Physics Ivica Puljak (Faculty of Electrical Engineering, Mechanical Engineering and Naval Architecture, University of Split, Croatia), a member of the Croatian research team at CERN. The lesson served to inform students about all the relevant facts of the CERN project to the extent to which the students were interested. The students were also given the opportunity and encouraged to ask questions. Professor had a lively discussion with students.

The following 8 sessions were dedicated to the presentation of the contents by the students' teams who used standard lecture mode aided by a number of visually rich Power Point? presentations. The rest of students used their notebooks to record important information and particular characteristics of each experiment. No particular discussion was noticed among the students in this phase of the project, although the teacher tried to encourage students' oral questions. Only the members of "critique team" had to record all their questions and pass them in written form to the presenting teams. These questions were answered later in two discussion sessions. The seating arrangement was strictly set and the teacher - researcher conducted the session and directed the classroom dynamic.

Two of the last three project sessions were reserved for students of two presenting teams to answer the questions posed previously by the "critique team". Finally, in the last session of the project, the critique team was asked to prepare and conduct a debate about all "open issues" which, according to them, were not treated conclusively. The debate triggered a number of interesting opinions about the project and the studied topics.

### 2.2.2. *Experimenting and Discussion (ED)*

ED pedagogy was applied to a group of three physics sections (85 students) who covered several classical physics topics in an active-learning way. As known from the previous studies, some of the sequential tasks which promote active learning are:

(1) Predict–Observe–Explain [41]; or

(2) Observe–Explain–Predict–Test [42,43].

These physics learning sequences activate the existent students' knowledge and test it by comparing the predicted and the observed. These sequences of active learning were carried out by using simple experiments to treat a selection of physical phenomena for which students' alternative conceptions are well known [44-46]:

(a) Force and the concept of motion (4 sessions)

(b) Pressure (hydrostatic, hydraulic, atmospheric, hydrodynamic) (4 sessions)

(c) Heat (4 sessions).

The teacher organized the teaching process in such a way that one simple experiment was carried out every session. At the beginning of each session an experiment was described to the students without actually carrying it out. The students were asked to predict the possible results of the experiment. Both the predicted results and their physical explanation had to be noted down in their notebooks. Then, they were asked to give their own predictions and the rationale for the anticipated results. Once the possible results of the experiment were defined, *i.e.* when groups of students with the same 'physical' views were formed, the students were able to debate and offer their explanations for the expected results. The debate allowed the students' preconceptions and the level of scientific reasoning to be clearly recognized by the instructor and also by the students themselves.

After the debate, the experiment was conducted by the teacher and the results were observed and recorded in the instructor's diary. Surprising results of experiments always provoked students' delighted reactions and positive emotions. They often asked to repeat the experiment themselves because they did not believe the observed result was possible. Naturally, the teacher would then let the students to carry out the experiment themselves. The experiments were followed by another debate based on the reasons for predicting different outcomes of the experiment. This discussion, guided and helped by the teacher, led to the construction of a more accurate physical explanation of the observed phenomenon.

The seating arrangement was informal, in particular during the experiment itself. The students wanted to be as close as possible to the place where the experiment had been carried out and they were also given the opportunity to do it themselves.

Examples for each of the above-mentioned sequences of active learning were presented elsewhere [47,48].

In the course of the project, students gladly participated in situations enabling them to acquire new knowledge. They also recognized equivalent situations in their everyday life, which enabled a positive shift from their previous conceptions and knowledge. Students often reported observing and discussing physical phenomena in out-of-class situations.

The students who did not actively participate in regular physics classes often showed a great engagement in active learning sessions. We found that students were able to direct the learning process themselves, and to seek improvement of their initial answers without fearing bad grades or reprimands.

## 3. Gender Characteristics Of Two Groups And Survey Application

The above described, non-traditional methods of designing physics learning were applied in a course of the academic year 2008/09 in the spring semester with the senior students. As was already said, the total number of students that took part in the research was 176, out of which 110 were girls and 66 were boys. They all come from 6 different classes of the same high school.

The total number is broken down into two groups for the purpose of the experiment, each group consisting of three classes. The RPQ group consists of 91 students altogether, out of which 56 girls and 35 boys, while the ED group consists of 85 students, out of which 54 girls and 31 boys (see Table I).

The research task was to measure how two different methods of physics learning affect students' attitudes and beliefs about the attractiveness of physics. In this study we used a survey which was administered at the beginning of each semester (pre-test) and again in the last week of the semester (post-test). The survey consists of 4 statements presented in the Study Design.

The students expressed their attitudes choosing one option on a 5-point Likert scale:

- I strongly disagree (graded as "- 2");
- I disagree (graded as "-1");
- Neutral (graded as "0");

TABLE I. Gender information for groups surveyed.

| | **All students** | **RPQ group (Reading, Presenting and Questioning)** | **ED group (Experimenting and Discussion)** |
|---|---|---|---|
| **Girls** | 110 (63%) | 56 (62%) | 54 (64%) |
| **Boys** | 66 (37%) | 35 (38%) | 31 (36%) |
| $\sum$ | 176 (100%) | 91 (100%) | 85 (100%) |

- I agree (graded as "+ 1") and
- I strongly agree (graded as "+2").

The positive attitude consists of both "I agree" and 2 "I strongly agree".

The dominant attitude is, so called,, the mean attitude". It is calculated by summing up all the students' answers and then obtaining the mean value, which can be in the range between -2 to 2.

Apart from expressing their attitude using the Likert scale, the students were given the possibility of explaining their choice.

We analyze below the overall pre and post results of the survey for each group. All evaluated students submitted valid pre and post tests, so all data is matched and represents 100% of the students in the courses.

Within the broader framework within which this study was carried out, students were classified, according to the level of scientific reasoning, into the Concrete thinkers, Transitional thinkers and Formal thinkers. For this purpose the "Lawson's Classroom Test of Scientific Reasoning" (LCTSR) [49] was used. So, we were able to study the relationship between attitudes toward studying physics and scientific reasoning level of students, too.

## 4. Results and Analysis

We will first analyze the change in the percentage of students with positive attitudes towards the statements of the survey. Pre and post percentages of students with a positive attitude are shown in Table II. Also shown are the results by gender of students, as well as the shift (Pre - Post).

For RPQ group of students, the results of the first statement show that on the pre-test only 12% of students consider physics to be the most interesting school subject, with 14% among boys and 11% among girls. After the project, girls made a progress of 14% to overall 25%, while young men show a gain of 6% to overall 20%. Overall, upon completion of the project additional 11% to overall 23% of students considered physics the most interesting school subject. With respect to the second statement, 63% students expressed positive attitudes on the pre-test. It is interesting to notice that on the pre-test the boys have substantially worse attitudes than girls (Table II). On the post-test both girls and boys make a statistically significant shift. The overall shift of RPQ group for this statement is 12% to overall 75%, which is also statistically significant ($p < 0.05$). For the third statement the students of this group show a high percentage of positive attitude on the pre-test (Table II). However, only boys show a significant improvement in attitudes at the end of the project, while girls do not change attitudes. As for the fourth statement students the percentage of positive attitudes on the pre-test was 26%. On the post-test boys show a negative (but not significant) shift while girls statistically significantly contribute to the negative shift with –14% (Table II).

As shown in Table II there are significant differences between the results of the RPQ and the ED group in the pre-test results.

The results of the first statement on the pre-test in the ED group are also low and they amount to only 15% (Table II). After the project all students achieve a significant shift of 37% to overall 52%. The pre-results of the second statement show that 59% of students have a positive attitude towards the attractiveness of physics because of the wide range of its applicability. On the post-test a significant positive shift of 29% to overall 88% has been gained on overall level, with the girls 35% and the boys 19%. 72% of students at the

TABLE II. Changes in the percentage of students with a positive attitude towards the statements of the survey (Pre-Post) for RPQ and ED Group (Large Shifts in Bold – $p < 0.05$).

| Statement: | | **RPQ group (N=91) (Positive attitude)** | | | **ED group (N=85) (Positive attitude)** | | |
|---|---|---|---|---|---|---|---|
| | | Pre (%) | Post (%) | Shift (%) | Pre (%) | Post (%) | Shift (%) |
| *1.For me, physics* | Overall | 12.1 | 23.1 | **11.0** | 15.3 | 51.8 | **36.5** |
| *is the most interesting* | Girls | 10.7 | 25.0 | **14.3** | 14.8 | 51.9 | **37.1** |
| *school subject* | Boys | 14.3 | 20.0 | **5.7** | 16.1 | 51.6 | **35.5** |
| *2. The attractiveness of* | Overall | 62.6 | 74.7 | **12.1** | 58.8 | 88.2 | **29.4** |
| *physics is determined by the* | Girls | 67.9 | 76.8 | **8.9** | 57.4 | 92.6 | **35.2** |
| *wideness of applicability of its concepts.* | Boys | 54.3 | 71.4 | **17.1** | 61.3 | 80.6 | **19.3** |
| *3. The attractiveness of* | Overall | 72.5 | 75.8 | 3.3 | 71.8 | 97.6 | **25.8** |
| *physics is determined by its* | Girls | 69.6 | 69.6 | 0.0 | 72.2 | 98.1 | **25.9** |
| *frequently surprising experiments.* | Boys | 77.1 | 85.7 | **8.6** | 71.0 | 96.8 | **25.8** |
| 4. *The attractiveness of* | Overall | 26.4 | 16.5 | **-9.9** | 18.8 | 17.6 | -1.2 |
| *physics is determined by the* | Girls | 25.0 | 10.7 | **-14.3** | 16.7 | 16.7 | 0.0 |
| *elegance of its mathematical formulas.* | Boys | 28.6 | 25.7 | -2.9 | 22.6 | 19.4 | -3.2 |

TABLE III. Dominant attitude (numerical value of the mean attitude) (Pre – Post) and its shift by survey statements for RPQ group and ED group (-2 – I strongly disagree; -1 – I disagree; 0 - neutral; 1 – I agree; 2 – I strongly agree; Large Shifts in Bold – $p < 0.05$).

| Statement: | | THE AVERAGE OF ATTITUDE (mean) | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | GIRLS | | | BOYS | | | TOTAL | | |
| | | Pre | Post | Shift | Pre | Post | Shift | Pre | Post | Shift |
| **RPQ group** | **1.** | -0.68 | -0,41 | **0.27** | -0.80 | -0.51 | **0.29** | -0.73 | -0.45 | **0.28** |
| | **2.** | 0.64 | 1.12 | **0.48** | 0.46 | 1.03 | **0.57** | 0.57 | 1.09 | **0.52** |
| | **3.** | 0.63 | 0.63 | 0.00 | 0.89 | 1.06 | 0.17 | 0.73 | 0.79 | 0.06 |
| | **4.** | -0.21 | -0.61 | **-0.40** | 0.11 | 0.03 | -0.08 | -0.09 | -0.36 | **-0.27** |
| **ED group** | **1.** | -0.78 | 0.39 | **1.17** | -0.74 | 0.42 | **1.16** | -0.76 | 0.40 | **1.16** |
| | **2.** | 0.41 | 1.37 | **0.96** | 0.48 | 1.16 | **0.68** | 0.44 | 1.29 | **0.85** |
| | **3.** | 0.59 | 1.81 | **1.22** | 0.71 | 1.84 | **1.13** | 0.64 | 1.82 | **1.18** |
| | **4.** | -0.61 | -0.74 | -0.13 | -0.13 | -0.32 | -0.19 | -0.44 | -0.59 | -0.15 |

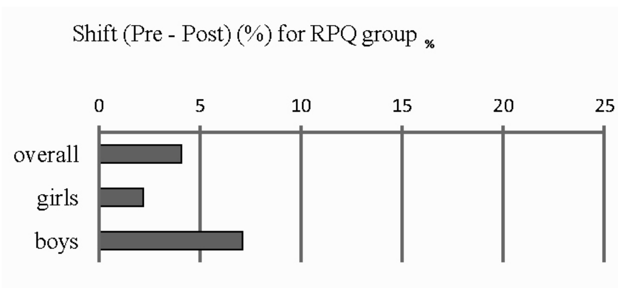


FIGURE 1. The shift of the percentage of students with positive attitudes on the overall level (Pre-Post) for RPQ group.

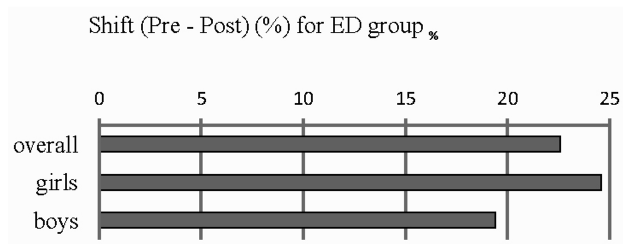


FIGURE 2. The shift of the percentage of students with positive attitudes on the overall level (Pre-Post) for ED group.

pre-test express positive attitudes related to the connection of attractiveness of physics and surprising experiments (third statement). At the post-test the results demonstrate the same significant shift for both genders which amounts to 26% to overall 98%. Students of this group had significantly lower results on the pre-test with the fourth statement compared to the RPQ group (Table II). Boys have more positive attitudes on the pre-test than girls. After the project there were no statistically significant shifts either with the girls or with the boys (Table II).

The shift in percentage of students with positive attitudes within the whole survey for RPQ and ED group is showed on Fig. 1 and Fig. 2. The RPQ group achieves a statisticaly significant shift of 4% (see Fig. 1), while the ED group has accomplished a significantly higher progress of 23% (see Fig. 2).

Let us observe the shift in the dominant attitude (numerical value of "the mean attitude").

The dominant attitude and its change (Pre – Post) depending on the gender of the student of observed groups is given in the Table III.

For RPQ's first statement, related to the attractiveness of physics as a school subject, overall average of attitudes is -0,73, where girls show less negative attitude than boys (Table III). At the post-test both girls and boys achieve a significant shift of 0.28. In the second statement about the applicability of physical concepts, students show positive attitudes at the pre-test with the average of 0.57. After the project, the shift is significant in attitudes of both genders. Although the mean attitude for the third statement (the one about surprising experiments) of the pre-test is the most positive one, there is no significant shift in the average of the attitude at the post-test. The students of this group show neutral attitude towards the fourth statement, the one about the attractiveness of physics created due to the elegancy of mathematical formulas. At the post-test boys do not show a significant decline of mean attitude, while girls do (Table III).

All students in the ED group had negative mean attitude for the first statement, the one about the attractiveness of school physics (Table III). At the post-test both girls and boys show a significant statistical change in the mean attitude. Students' attitudes towards the attractiveness of the application of physical concepts (second statement) have an average of 0.44 at the pre-test, and it is similar for both sexes. At the post-test, both girls and boys achieve a statistically important progress. Students' attitude towards the attractiveness of school physics created by surprising experiments (third statement) is determined at the pre-test by the mean attitude of 0.64 for all students, of which boys are slightly more positive than girls. At the post-test students achieve the biggest shift from all the statements, to which girls contribute significantly (Table III). Students have different mean attitudes (regarding the sex) towards the fourth statement, which is about the attractiveness of physics created by elegancy of mathematical

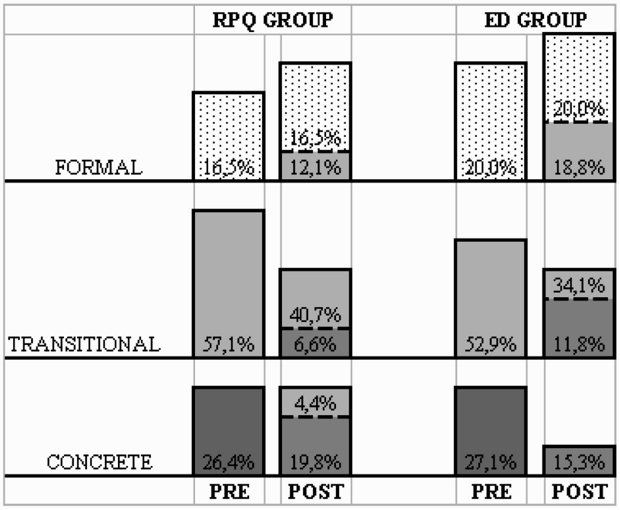


FIGURE 3. Pre - to - post migrations between different levels of thinking for RPQ and ED groups.

formulas. Girls have significantly more negative attitude than boys. At the post-test neither girls nor boys show a statistically significant changes in the mean attitude (Table III).

### 4.1. Attitudes toward studying physics and scientific reasoning level of students

In course of the project there was a migration of students in higher or lower levels of reasoning [47]. These results are shown in Table IV and Fig. 3.

Table IV shows the pre–post-test results in terms of levels given by the Lawson test.

TABLE IV. Percentages of RPQ and ED students in concrete-operational, transitional, and formal-operational thinking categories as indicated by pre - and post-test scores on the LCTSR.

| | | Concrete | Transitional | Formal |
|---|---|---|---|---|
| RPQ group (%) | Pre | 26.4 | 57.1 | 16.5 |
| | Post | 24.2 | 47.3 | 28.6 |
| ED group (%) | Pre | 27.1 | 52.9 | 20.0 |
| | Post | 15.3 | 45.9 | 38.8 |

It can be seen that there were substantial gains towards formal operations shown by both the RPQ and ED groups (Table IV). For the ED group the proportion showing formal-operational thinking has almost doubled, and for RPQ has improved by a factor of 1.73.

Observing the Fig. 3 it is evident that formal thinkers of both groups have not migrated at all. At the same time, in the ED group there is a greater migration towards higher levels of scientific reasoning compared to the RPQ group.

By observing the results that are showed in the Table V, it is evident that RPQ group's concrete and transitional thinkers do not achieve a statistically significant shift in the mean attitude. Only formal thinkers achieve a significant shift in the mean attitude (0.30).

All groups of thinkers in the ED group achieve statistically significant gains in the mean attitude (Table V). Concrete thinkers achieve the biggest shift (1.01); transitional thinkers have the shift of 0.82, while formal thinkers have the shift of 0.28.

TABLE V. Dominant attitude (numerical value of the mean attitude) (Pre – Post) and its shift according to the groups of thinkers within the whole survey for RPQ and ED group (-2 – I completely disagree; -1 – I disagree; 0 - neutral; 1 – I agree; 2 – I strongly agree; Large Shifts in Bold – $p < 0.05$).

| | **THE AVERAGE ATTITUDE for the whole survey (mean)** | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | Concrete | | | Transitional | | | Formal | | |
| | Pre | Post | Shift | Pre | Post | Shift | Pre | Post | Shift |
| **RPQ group** | -0.08 | -0.10 | -0.02 | 0.19 | 0.37 | 0.18 | 0.20 | 0.50 | **0.30** |
| **ED group** | -1.02 | -0.01 | **1.01** | 0.12 | 0.94 | **0.82** | 0.90 | 1.18 | **0.28** |

## 5. Discussion

Acquiring contemporary physics knowledge using the RPQ method enhances more the interest of girls than the interest of boys. Although processing the proposed topics implies a significant amount of technical data which girls mostly do not find highly interesting, it also contains a significant amount of discussion organised by the team of critics. It is the discussion part that has left a good impresion with the girls and has increased their interest in physics as a school subject. On the other hand, the boys of this group are better at recognizing the applicability of physical concepts and they are more interested in the experiments used to enable new understanding because of their technical backround. While mathematical formulations of physical laws dominate the traditional educational system, in the new method of learning – RPQ method, such formulations are significantly reduced. Girls recognize it as a positive characteristic of the new method which results in the reduction in the number of girls who see the attractiveness of physics in the elegance of mathematical formulas. Boys experience the new method differently on this field of physics' attractiveness as well. They do not change significantly their attitude regarding mathematical formulas in physics. Formal thinkers are the only ones who achieve a shift in their attitudes on the level of the entire survey. This fact leads to a conclusion that RPQ method with contemporary topics is not suitable for the increase of interest in physics with those students who are on a lower level of scientific reasoning. However, the increase of interest in those students is essential for achieving a higher quality of physics education as a whole.

"Old physics knowledge" acquisition with the ED method through sequence *Predict – Observe – Explain* or *Observe – Explain – Predict – Test* results in remarkable gains in the change of attitude with both genders. It is evident that the learning based on simple experiments provides good results in the increase of interest in school physics. Discussions about the experiment, the possibility of personal interpretation and recognition of physical phenomena in everyday life leave a distinctly positive influence on the interest of girls in physics class, which is one of the main goals. The students of this group do not change attitudes about the attractiveness of physics determined by the elegance of mathematical formulas. ED method of learning is based on surprising experiments, therefore this dimension of possible interest was dominating in the process of learning. It is important to emphasise that concrete thinkers achive significant gains which indicates that ED method can contribute to the quality of physics learning and teaching.

Although the ED method obtains excellent results, it has to be emphasized that, due to its experimental nature, it is not equally applicable to all physics topics. For example, although highly appropriate for classical physics topics, it would be inappropriate for addressing quantum physics topics.

## 6. Conclusion

This study presents the results of attitude change of senior high school students related to the attractiveness of physics and analyses the changes of those attitudes in dependence of the method of teaching. Pre-results of testing show that less than 16% of senior high schools students consider physics to be the most interesting subject. Such percentage surely hinders acquisition of complex physic concepts for a large number of students. Physics courses in Croatian elementary schools, high schools and universities are often characterized by traditional teaching, ready-made recipies for problem solving, alghoritmic homework and tests.

We have considered ways of changing the students attitude towards the attractiveness of school physics and have therefore observed in what ways different methods of teaching and learning physics can result in a positive effect on the change of that attitude.

Prompted by that question we have observed the results of two different learning designs: RPQ (reading, presenting and discussing modern physics subjects) and ED (experimenting and discussing "classical physics" subjects, for example the prediction, observation and explanation of simple phenomena). The results indicate that in one semester both the RPQ and the ED method have improved the attitudes of students towards the attractiveness of physics. However, it is also evident that the results of learning physics by the ED method, in combination with easy-to-create surprising physical phenomena, are better for both sexes. This is particularly true for students which were on the concrete level of reasoning. The ED method (with „old" topics) proves to be a good way to improve attitudes of students towards physics in general and as a school subject, which is an important prerequisite for improving physics knowledge aquisition and for changing the students into persons, who are aware of their potential for following scientific careers. Contemporary physics topics, even when treated in new learning format like in RPQ group, are less effective in improving attractiveness of school physics.

Accordingly, the whole teaching process should be modified in order to meet students' interests by changing both the classroom activities and the teaching materials. However, this process is highly complex and, in order to succeed, it requires the efforts not only of the teachers but from whole educational community.

## Acknowledgements

We thank Mr Mladen Buljubašić, prof., Ministry of Education coordinator for physics, for granting the permission for using up to a quarter of annual syllabus (16 lessons) for the project. We also want to thank Professor S. Pivac for the great support and effort she put into processing data.

$i$. The term "learning packages" stands for a combination of learning/teaching methods and a set of topics that is addressed by this method.

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