Students' Experiences in Learning Physics: Active Learning Methods and Traditional Teaching

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Abstract
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 (active learning methods), called *Reading, Presenting, and Questioning* (RPQ) and *Experimenting and Discussion* (ED), in relation to traditional teaching of physics. The survey has been conducted on a sample of 176 students who attend the final year of a high school in Split (Republic of Croatia). The data of a one-semester-long high school project indicate that 36% of students of RPQ group choose the new method, the traditional method is the choice of 41% and the combination of the two methods is chosen by 23%. On the other hand, 91% of ED group students choose the new method, 1% choose the traditional one and 8% the combination of the two methods. It is important to emphasize that all concrete thinkers of the ED group choose the new method of learning physics as the one that should be carried out in the entire physics teaching.

Keywords: Active physics learning; Reading, Presenting and Questioning method; Experimenting and Discussion method; Traditional physics teaching.

Resumen
En esta investigación hemos usado un cuestionario especialmente preparado con el fin de evaluar la eficacia relativa do dos diferentes diseños de las actividades de aprendizaje para estudiantes (métodos de aprendizaje activo), llamados Leer, Presentar y Cuestionar (RPQ por siglas en inglés) y Experimentar y Discutir, en relación con la enseñanza tradicional de la física. La encuesta fue realizada con una muestra de 176 estudiantes quienes han cursado el último año de una escuela preparatoria en Split (Republica de Croacia). Los datos de un proyecto escolar, que duró un semestre, indican que 36% de estudiantes en el grupo RPQ eligen el nuevo método, el método tradicional es elegido por 41% y la combinación de dos métodos es la elección de 23% de estudiantes. Por el otro lado, 91% de estudiantes en el grupo ED eligen el nuevo método, 1% eligen el método tradicional y 8% de estudiantes prefiere una combinación de dos métodos. Es importante enfatizar que todos los pensadores concretos en el grupo ED han elegido el nuevo método con que debería realizarse toda la enseñanza de la física.

Palabras clave: Aprendizaje activo de física; método "Leer, Presentar y Cuestionar"; método "Experimentar y discutir"; Enseñanza tradicional de física.

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I. INTRODUCTION

Students have attitudes, beliefs and expectations about learning physics that can affect the way they behave and learn during physics class [1, 2].

Actual results mainly depend on what is really going on in the classrooms. If the scientific knowledge is introduced as proven facts and the absolute truth given through the texts and lectures, students will perceive the science as the static body of knowledge that is based on well-defined methods [3].

For students, this kind of knowledge consists of the structure of memorized information. On the other hand, students, who actively participate in the science processes, are able to see that scientific knowledge is based on the experiments from which the data is obtained and that the theories are not absolute.

In that context, their knowledge consists of learning experimental method, norms and practice of scientific communities to that extent in which the known facts and the current theories are within their domain [4].

These two orientations of scientific knowledge in teaching approximately match the two different approaches in teaching. In the teaching process that puts the teacher in the centre, learning is focused on the content with diminished development of skills and attitudes that are necessary for scientific query. The teacher communicates information to the students who receive it and memorize it. The assessment of knowledge usually includes just one right answer. The curriculum is carried out through many facts and a vast number of words, which encourages lecturing type of teaching [5].

On the contrary, learning of natural science should be active and constructive. The aim is to develop critical thinking and problem solving skills by asking and examining relevant questions whose answers must be discovered. The teachers act as a guide and create the learning environment where students actively participate in the experiments. They also interpret and explain the data and negotiate the understanding of the experiments' findings with associates and colleagues.

In this model the teacher puts less emphasis on memorizing information, while the strong emphasis is put on query and direct activity through which students develop deeper knowledge and understanding of the nature of science [6].

In high schools where the typical curriculum is applied, the students do not have many opportunities to participate in the activities based on queries [5], and are not immersed in the adequate learning environment which would include them in scientific discussions and where they would be able to explain and defend their points of view [7].

Active methods of teaching and learning are subject to a number of discussions regarding education at both national and international level [8, 9]. Recent learning studies recognize a number of different approaches that emphasize student activity [10]. In modern psychology of learning, many concepts, such as authentic learning, self-directed learning, self-regulated learning, independent learning, autonomous learning, solving problems and active learning all have the same purpose, even if they originate from different theoretical frameworks. They all have one thing in common:

The student is an active participant of the learning process. Active roles are manifested in individual and cooperative learning strategies [11].

Promoting active learning in the classrooms has a significant effect on the teacher's role [12]. Active learning studies [9] have discovered a new pedagogical role of the teachers who wanted to encourage their students to become active constructors of knowledge. They have become mediators and the bigger responsibility has been given to students themselves. Those teachers had a more democratic approach: with their students they negotiate their goals, methods and learning control.

During the past decade, the researchers and instructors all over the world were trying to promote active learning through academic courses. The process of introducing teaching innovations, based on acquiring active teaching approaches, is long and complex [13]. In many teaching areas it is difficult to introduce innovations despite the obvious fact that it could be favourable and useful [14].

A lot of evidence supports the theory that active learning brings bigger conceptual understanding when compared to other students who frequented the same courses where the traditional approach was used [15]. In the big study conducted on a sample of 6500 students who used the active method of learning, Hake (1998) established that they significantly improved their conceptual understanding of mechanics when compared to students who used traditional methods of learning [16].

When it comes to active learning, teamwork in small groups plays a significant role in teaching. Using exercises while solving problems directs students to pay attention to their own opinion and solving strategies.

Newly developed knowledge is organized, analysed, applied and evaluated through different thinking processes [17]. In a number of cases, students offer their solutions and each one of them has its advantages and disadvantages. Uncertainty is an immanent part of higher-order thinking that requires a certain level of independence, judgment and deciding [18].

The majority of teachers have the tendency to stick to the traditional teaching approach, according to which the main function of the instructor is to communicate knowledge, disregarding the other important component: the students' expectations from learning [19]. In many cases, students prefer the learning style that enables them to passively participate in lessons, where the instructor clearly presents teaching material and solves all the problems that are expected to be a part of their final exam [20]. Students, as well as teachers, who are used to the traditional learning don't want to adapt to new learning environment. Therefore, instructors who want to apply the new methods are often frustrated by the answers of their students [21].

The variety of teaching methods and curriculums have been developed in order to meet all of the aspects of standard physics courses. Most of them are based upon constructivism [22]. Constructivist approach to knowledge and learning emphasizes the active role of the student, his interaction with the environment and the interpretation of information regarding his previous experiences [23].

Principle design for the creation of constructive learning environment includes the assignment of open type, authentic and challenging tasks, allowing the students to cooperate with their colleagues and they offer suitable levels of activity [24]. Physics programmes that include alternative problems and teamwork are *Problem-Based Learning* [25] and *Cooperative Group Problem Solving* [26]. Other teaching strategies that use teamwork and cooperative learning in the classroom are *Physics by Inquiry* [27], *Tutorials in Introductory Physics* [28], *Workshop Physics* [29], *Studio Physics* [30], *SCALE-UP* [31], and *TEAL* [15].

Another constructivist approach is based on instructions for using learning cycles [32]. Three-phase cycle of learning includes exploration, introduction of the concept and the application of the concept [32]. Both approaches have the initial "research" period during which the students participate through their own activity before the concept is formally introduced. There are some teaching curriculums of physics laboratories that incorporate this aspect of early research, such as *Physics by Inquiry* [27], and *Investigative Science Learning Environments* [33].

Using technology in teaching often acts as useful method for improving students' interest. This conclusion is in line with previous reports on positive influence of technology on improving the students' interest and motivation during the class [34], as well as other learning outcomes [35]. Technology can improve students' interest by relating them to real phenomena which results in the promotion of the feeling of authenticity, offers simple approach to the source of information and at the same time attractively offers alternative ways of learning [36]. However, it is important to emphasize that with the very act of inclusion technology in the process of teaching curriculum ceases to be interesting [37].

Recent finding emphasizes the need to stress the specific type of activities included in curriculum development. Though it seems extremely important, it is insufficiently present in the recent efforts to improve educational sciences [37]. While it is being discussed which materials are to be included in curriculum, the usage of these materials remains unclear. Furthermore the strong emphasis is on the development of important goal (such as: solving important problems, conducting projects that are a result of students' personal interests) in the process of teaching in order to increase students' engagement [36, 38]. Meanwhile, not enough is being said about shape, sequence, and the structures of the activities through which these goals should be integrated into curriculum. In other words, it seems that the students' activity itself is not of great concern in those efforts. Nonetheless, we believe that the one thing that is missing is a thorough understanding of the affects that these specific ways of acting have on students' cognitive and affective learning outcomes.

Palmer (2009) set a good example of such a research, questioning how different phases and activities influence students' interest [39]. Similar efforts are necessary in finding which students' activities are interesting; what makes a sequence of students' activity effective; which activities are adequate for different teaching materials and learning goals; and what are the priority activities for different students' target groups.

Considering that the teaching frameworks provide dominant influences on what physics courses can offer to students, goals and teaching methods of these courses should be seriously taken into consideration. This study considers how school educational system, that is directly included in teaching, can strongly influence the changes in students' attitudes towards physics. Guided by this thought we have observed two new didactic designs of student active learning: *Learning Physics through Reading, Presenting and Questioning* (RPQ – method) and *Learning Physics through Experimenting and Discussion* (ED - method) and we have explored students' attitude towards experienced form of active learning in relation to *Traditional Method of Learning Physics.*

II. STUDY DESIGN

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

How do students assess two new physics teaching methods with additional students' activities: *Reading, Presenting, and Questioning* (RPQ) and *Experimenting and Discussion* (ED) in relation to the traditional method of learning physics?

A. General information about students and curriculum

This research was conducted with 6 complete physics sections of senior students (17 – 18 years) in the last grade of a high school in Split (Croatia) during spring semester of 2009. This period was particularly suitable for conducting the project because the students were in the last semester of their high school education and already possessed knowledge from different scientific areas as well as attitudes towards them. The total number of students was 176 and they studied a classical and language - oriented curriculum. Although the study program is language - oriented, the students may decide to attend different courses at university level: from humanities to scientific and technical studies. However, it should be emphasised that students from humanities oriented high schools rarely consider physics as their possible career option. In the Republic of Croatia there is no major difference between different high school programs.

They all try to prepare students for a vast area of university study programs. Namely, students are given the opportunity to find their real field of interest that often changes in the period of the four high school years. Therefore, the curriculum also includes science subjects, such as biology, physics**,** and chemistry, which are present in the curriculum with two lessons per week, throughout the high school education.

The research on non – traditional active teaching methods lasted one semester (spring semester) and was carried out with two groups of students, each group consisting of three physics sections. Both groups studied the topics that are set by the annual syllabus [40]. The main themes are energy spectra, atomic nuclei, elementary particles, evolution of Cosmos and deterministic chaos.

Within the obligatory physics curriculum, there is some time, limited to one 45-minute session per week, allocated to the free topic formation. This means that, apart from the topics set by the syllabus, the teacher is allowed to introduce some additional themes that may reflect his/her or preferably the students' interests. This free topic time was the time 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 themes and 4 sessions for pre and post assessments. The themes were chosen by researchers.

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

B. The two different pedagogical methods promoting active learning

B.1 Reading, Presenting, and Questioning (RPQ)

RPQ pedagogy was applied to a group of three physics sections (91 students) by introducing 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–researchers,

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

(iii) Students' presentations of the learning results in PowerPoint™ format,

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

The rationales behind this design was derived from successful practices like 'read to learn" [41], "present to learn" [42], and "question to learn" [43].

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 analyse and evaluate reading materials and question the peers who were presenters.

The students chose the teams themselves, depending on their interests, as well as on the level of proficiency in physics. In the case when the choice was questionable, the teacher resolved the problem by assigning students to a suitable team.

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 [11] and Johnson and Johnson [44]. 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 that would reveal the cognitive processes, emotions**,** 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. A significant interest in the project on behalf of a number of students was noticed, as well as a lively communication with Professor Puljak.

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 PowerPoint™ presentations. The rest of students used their notebooks to record important information and particular characteristics of each experiment. No particular oral 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 it was the teacher - researcher who always conducted the session and controlled the classroom atmosphere.

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.

B.2 Experimenting and Discussion (ED)

ED pedagogy was applied to a group of three physics sections (85 students) that were supposed to cover some classical physics topics in an active-learning way. As it is widely known, some of the sequential tasks that promote active learning are:

(1) Predict–Observe–Explain [45]; or

(2) Observe–Explain–Predict–Test [46].

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 [47]:

(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, personal explanations of 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 both the instructor and the students themselves.

After the debate, the teacher carried out the experiment and the results were observed and recorded. Surprising results of experiments always provoked students' delight and positive emotions. They often asked to repeat the experiment themselves because they did not believe the resulting outcome was possible. Naturally, the teacher then always required the students to carry out the experiment themselves. The experiments were followed by another debate based on the reasons for predicting certain results of the experiment. This discussion, guided and helped by the teacher, led to the construction of a better 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 was being 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 [48,49].

In the course of the project, students participated gladly in situations enabling them to obtain new knowledge. They also recognized those situations in everyday life, which make possible a positive shift in their previous conceptions and knowledge. Student discussions about the physical phenomena observed in the classroom were also noticed in out-of-class situations.

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

III. 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. 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 certain knowledge from different scientific areas as well as attitudes towards them. 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 (Table I).

TABLE I. Gender information for the involved groups.

	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%)
∑	176 (100%)	91 (100%)	85 (100%)

The aim of this study is to observe students' evaluation of the traditional physics learning as well as physics learning with additional students' activities. The first teaching method, applied in the obligatory part of the curriculum will be called the "traditional method". The other teaching method, applied in the "free topic time" to promote active learning, was called in students' survey questions simply "new method".

In this study, we have used a survey that was conducted at the end of the project, that is, in the last week of the semester. The survey was composed of 13 questions:

1. How would you briefly describe the "traditional method"?
2. List the things that you like the most about the "traditional method"?
3. List the things that you didn't like at all about the "traditional method"?
4. Which moments of the "traditional method" would you describe as the most beautiful and the most exciting?
5. When the "traditional method" is applied in teaching, what are your general feelings?
6. To which extent and why is the "traditional method" suitable to your way of learning and to your character?
7. How would you briefly describe the "new method"?
8. List the things that you like the most about the "new method"?
9. List the things that you didn't like at all about the "new method"?
10. Which moments of the "new method" would you describe as the most beautiful and the most exciting?
11. When the "new method" is applied in teaching, what are your general feelings?
12. To which extent and why is the "new method" suitable to your way of learning and to your character?
13. If only one method should be applied in the entire physics learning, would you choose the traditional or the new method and what would be your reasons?

The survey consisted of three parts. The first six questions aim at revealing students' experiences and attitudes about the "traditional method" of learning physics. The next six questions are about gathering information about the "new method" of learning physics. The last question of the survey offers a choice between the two observed teaching methods and concludes this study.

The results will also be divided in three parts. For the "traditional method" part, the first six questions will be analysed; for the "new method" part we will take into consideration the next six questions. Finally, the results of the last question will be considered independently.
In order to analyse the results of the first twelve questions in detail, eleven categories have been introduced. The name of the category is the result of joint students' argumentations that had the same starting point and because of that, could be classified under the same title.

A. Defining categories for comparing

Activity
Students actively participate in the realization of physics teaching (they analyse and conduct experiments and analyse and discuss the new physics scientific discoveries).

Freedom of (non) participating in the teaching process
It is up to the student to choose whether he will be an active or a passive participant in the teaching process and its conduction.

Attractiveness
It is related to students' perceptions whether the observed physics teaching topics are interesting or not.

Inadequacy of physics as a school subject
The teaching of physics can hardly be represented through the observed way of teaching.

Breadth of the subject matter
The subject matter of the observed physics' topics is too wide; the students lack the necessary mathematical apparatus that would enable them to understand the matter; another thing that prevents them from understanding and seeing the entire picture of the observed phenomenon is the highly specialized terminology found in texts.

Boredom and dullness
Teaching process (the way of conducting it as well as the teaching topics) doesn't encourage active participation. Students stress the general feeling of boredom and dullness. Teaching process is not exciting enough.

Thinking encouragement
During the teaching process of physics, the student is encouraged to think and he accomplishes it through deep and correct understanding of physical laws.

Students' passivity
Students are passive participation in the realization of physics teaching.

Application in everyday life
It is recognized how the observed physical phenomena and physics knowledge can be applied in everyday life.

Positive feelings
Positive feelings are recognized during physics class, like positive excitement, happiness, joy and pleasure.

Subject matter accessibility
The student knows exactly what and how much to learn. Nothing remains unclear. There are no obscurities. He is not asked to analyse the observed physics subject matter on his own, or to apply it in everyday life.

IV. RESULTS

The analysis of the "*The Evaluation of the Two Physics Teaching Methods"* survey has been conducted in three parts.

A. "Traditional method" of learning physics

In this part we will analyse the results of the first six questions of the survey (questions no.1, 2, 3, 4, 5 and 6).

The results of the first six questions of the survey for the RPQ group are shown in Table II. The students of the RPQ group describe the traditional method by listing its main characteristics: inadequacy of physics as a school subject (21%), boredom and dullness (56%), students' passivity (42%) and subject matter accessibility, that is, the exact amount of subject matter given to the student (32%).

What students of this group like the most about the traditional method is freedom of (non) participating in the teaching process (24%), subject matter accessibility (38%). According to students the bad characteristics of the traditional method are: inadequacy of physics as a school subject (21%), boredom and dullness (59%), students' passivity (62%).

The most exciting and the most beautiful moments of the traditional method are related to the freedom of (non) participating in the teaching process (8%), attractiveness of the elaborated physics topics (16%), subject matter accessibility (8%), thinking encouragement process (16%) and the control over the amount of the subject matter that is exactly specified-subject matter accessibility (8%).

During the traditional teaching, 67% of the students feel bad, bored and dull, while only 16% of them feel positively. The rest of the students do not have any particular feelings during the traditional teaching. 12% of the students consider the traditional teaching to be a good teaching method due to freedom of (non) participating in the teaching process. 39% of them approve it because of the accessibility of subject matter that needs to be learned.

Table II shows the results of the first six questions of the survey for the ED group. The students of the ED group perceive the traditional method as unsuitable for physics as a school subject (78%). The main characteristics of that method are boredom and dullness (96%), students' passivity (89%) and accessibility of subject matter (7%).

TABLE II. The results of the RPQ and the ED group for questions 1, 2, 3, 4, 5 and 6 of "*The Evaluation of the Two Physics Teaching Methods"* survey.

RPQ group (%) Learning physics through Reading, Presenting and Questioning **ED group (%)** Learning physics through Experimenting and Discussion									
Category **QUESTION**	**Group**	Freedom of (non) participating in the teaching process	Attractiveness	Inadequacy of physics as a school subject	Boredom and dullness	Thinking encouragement	Students' passivity	Positive feelings	Subject matter accessibility
1. How would you briefly describe the "traditional method"?	RPQ			21	56		42		32
	ED			78	96		89		7
2. List the things that you like the most about the "traditional method"?	RPQ	24							38
	ED	9							11
3. List the things that you didn't like at all about the "traditional method"?	RPQ			21	59		62		
	ED			59	93		95		
4. Which moments of the "traditional method" would you describe as the most beautiful and the most exciting?	RPQ	8	16			16			8
	ED								
5. When the "traditional method" is applied in teaching, what are your general feelings?	RPQ				67			16	
	ED				89				
6. To which extent and why is the "traditional method" suitable to your way of learning and to your character?	RPQ	12							39
	ED								1

TABLE III. The results of the RPQ and the ED group for questions 7, 8, 9, 10, 11 and 12 of "*The Evaluation of the Two Physics Teaching Methods"* survey.

RPQ group (%) Learning physics through Reading, Presenting and Questioning **ED group (%)** Learning physics through Experimenting and Discussion									
Category **QUESTION**	**Group**	Activity	Attractiveness	Inadequacy of physics as a school subject	Breadth of the subject matter	Boredom and dullness	Thinking encouragement	Application in everyday life	Positive feelings
7. How would you briefly describe the "new method"?	RPQ	63	49	37	39		16		27
	ED	99	86				93	96	52
8. List the things that you like the most about the "new method"?	RPQ	62	54				42		50
	ED	96	96				93	96	99
9. List the things that you didn't like at all about the "new method"?	RPQ			21	42				
	ED			4					
10. Which moments of the "new method" would you describe as the most beautiful and the most exciting?	RPQ	74	56				52		36
	ED	99	86				96	98	94
11. When the "new method" is applied in physics what are your general feelings?	RPQ					21			66
	ED								99
12. To which extent and why is the "new method" suitable to your way of learning and your character?	RPQ	56	52				47		54
	ED	98	95				98	100	96

The students of this group do not offer much information about their preferences in the traditional teaching of physics. When it comes to the traditional method, 9% of students like the possibility of choosing between participating and not participating in the teaching process. 11% like subject matter accessibility. What they don't like about the traditional method is inadequacy of physics as a school subject (59%), boredom and dullness (93%) and students' passivity (95%). While analysing the surveys of this group of students, no records were found regarding the most exciting and the most beautiful moments in the traditional method. General feeling among the students during the traditional teaching process is boredom and dullness (89%). Only one student of this group (1%) considers that the traditional method suits her needs due to subject matter accessibility.

B. "New method" of learning physics

In this part we will analyse the results of the next six questions of the survey (questions 6, 7, 8, 9, 10, 11and 12)

Table III shows the results of the next six questions of the survey for the RPQ group.

Students of the RPQ group describe the new teaching method *(Learning Physics through Reading, Presenting and Questioning)* through the following categories: activity (63%), attractiveness (49%), thinking encouragement (16%) and students' positive feelings (27%).

Students of this group point out negative aspects of the new teaching method: inadequacy of physics as a school subject (37%) and breadth of the subject matter (39%). Students like the new teaching method because of students activity (62%), attractiveness (54%), thinking encouragement (40%), and students' positive feelings during the teaching process (50%).

Students also think that the new teaching method has its negative sides, among which the most dominant are: inadequacy of physics as a school subject (21%) and breadth of the subject matter related to the new scientific discoveries (42%). Students perceive the students' activity as the most beautiful and the most exciting moments of the new method (74%), attractiveness (56%), thinking encouragement (52%) and positive feelings (36%) during the application of the new teaching method. 66% of students recognise positive feelings during the application of the new teaching method, while 21% feel boredom and dullness. Students evaluate the new method as the teaching method that suits 56% of them due to their activity, while 52% like it because of the attractiveness of topics. 47% of the students consider it to be good because of thinking encouragement, and 54% because of positive feelings during the physics class.

Table III shows the results of the next six questions of the survey for the ED group. Students of the ED group describe the new teaching method (*Teaching Physics through Experimenting and Discussion*) using the following characteristics: activity (99%), attractiveness (89%), thinking encouragement (93%), application in everyday life (96%) and stimulation of positive feelings (52%). Exactly these characteristics are the ones the students like the most: activity (96%), attractiveness (96%), thinking encouragement (93%), application in everyday life (96%) and positive feelings (99%). Only one student (1%) considers the new method unsuitable for high-school physics class. 99% of students perceive the students' activity (99%), attractiveness (86%), thinking encouragement (96%), application in everyday life (98%), and the presence of positive feelings (94%) as the most beautiful and the most exciting moments of the new method. 99% of the students feel positively during the new teaching method. The new teaching method fits most of the students because of the category of activity (98%), attractiveness (95%), thinking encouragement (98%), application in everyday life (100%) and positive feelings (96%).

C. Choice of the teaching method

Finally, students' assessment of the "new methods" of learning physics are given through their answer to the last question (no. 13) of this survey:

If only one method should be applied in the entire physics teaching, would you chose the traditional or the new method and what would be your reasons?

The results of the question no. 13 of the survey for RPQ and ED groups are shown in the Table IV.

TABLE IV. The results of the RPQ and the ED group for question no. 13 of the survey "*The Evaluation of the two Physics Teaching Methods"*.

		Female	**Male**	**All students**
RPQ group (%)	New Method (RPQ – method)	25	54	36
	Traditional Method	48	29	41
	Combination of two methods	27	17	23
ED group (%)	New Method (ED – method)	91	90	91
	Traditional Method	2	0	1
	Combination of two methods	7	10	8

There's a significant amount of dispersion among students of RPQ group when choosing the teaching method that would realise the overall teaching of physics. 36% of the students choose new teaching method, 41% of them would choose the traditional method while 23% choose the combination of the two. Interestingly, a split is found between boys and girls. New method is mainly chosen by the boys (54%) in relation to the 25% of the girls. Traditional method is mainly chosen by the girls (48%) in relation to the 29% of the boys. The combination of the two methods is chosen by 27% of the girls and 17% of the boys of the RPQ group.

The students of the ED group mostly choose the new method (91%) as the teaching method that would render physics closer, comprehensive and more applicable for the majority of students. That choice is the same for both boys and girls. Of all the students only one girl chooses the traditional method while the combination of the two is chosen by 8% of the students of ED group (7% of girls and 10% of boys).

D. The relation between the students' level of scientific reasoning and their choice of the teaching method

Within the broader framework of the same study students were classified, according to the level of scientific reasoning, into the Concrete thinkers, Transitional thinkers and Formal thinkers (see Table V). For this purpose the 'Lawson's Classroom Test of Scientific Reasoning" (LCTSR) [50] was used.

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

	Concrete	**Transitional**	**Formal**
RPQ group (%)	26.4	57.1	16.5
ED group (%)	27.1	52.9	20.0

It is interesting to observe how different groups of thinkers in the RPQ and the ED group decide on teaching method which would realise the teaching of physics (Table VI).

For the RPQ group:
- The new teaching method is chosen by 33% of concrete, 40% of transitional and 27% of formal thinkers.
- The traditional teaching method is chosen by 29% of concrete, 44% of transitional and 46% of formal thinkers.
- 38% of concrete, 16% of transitional and 27% of formal thinkers choose the combination of the two teaching methods.

TABLE VI. Results according to groups of thinkers of the RPQ and the ED group for question 13 of the survey *"The Evaluation of the two Physics Teaching Methods"*.

		Concrete	**Transitional**	**Formal**
RPQ group (%)	New Method (RPQ – method)	33	40	27
	Traditional Method	29	44	46
	Combination of the two methods	38	16	27
ED group (%)	New Method (ED – method)	100	86	88
	Traditional Method	0	3	0
	Combination of the two methods	0	11	12

For the ED group:
- The new teaching method is chosen by 100% of concrete, 86% of transitional and 88% of formal thinkers.
- The traditional teaching method is chosen by 3% of transitional thinkers, while concrete and formal thinkers do not choose this teaching method.
- 11% of transitional and 12% of formal thinkers choose the combination of the two methods. Concrete thinkers do not choose the combination of the teaching methods.

V. DISCUSSION AND CONCLUSION

Physics courses in Croatian elementary schools, high schools and higher education institutions are mainly characterized by the traditional teaching, algorithmic homework and exams based on numerical problems.

This approach creates an academic surrounding in which there is no enough interest for physics as a school subject or as a possible profession. At the same time, we witness how the high school physics teaching frustrates a great number of students. The main reason behind this frustration is their inability to see how physics knowledge can be of use to them as well as the lack of motivation to explore the unknown.

Students of both observed groups clearly recognize negative elements of the traditional teaching. They see physics as a school subject that cannot be fully experienced through the traditional method of teaching. Their arguments are: lack of experiments and discussion, the separation of physics from everyday life and students' passivity.

When asked about the most beautiful and most exciting moments regarding the traditional method, the ED group students lack examples and argumentation. On the other hand, for the RPQ group students those moments are to the greater extent related to the subject matter accessibility and the freedom of (non) participating in the teaching process.

Students of different groups show similar feelings when it comes to the application of the traditional teaching method. Those feelings are mainly characterised as boredom and dullness.

The RPQ group students' positive attitude towards the traditional method is mainly encouraged by the organization of the subject matter, clearness and conciseness. The ED group students do not find any reasons why the traditional method should suit them.

What is emphasized is the lack of cognitive function in that type of teaching as well as the lack of learning through everyday life situations.

Positive sides of the RPQ method that students recognize are: the introduction of new, interesting discoveries about the universe, increased students' activity and discussion. However, students are critical about the frontal way of teaching carried out through reports and lectures. Also, they are not happy about the inability to see the entire picture of the observed phenomenon and the highly specialised terminology found in texts.

Students are fond of all the main characteristic of the ED method: deep and accurate understanding of the physical laws, the increased students' activity achieved through discussion and other activities, the change of attitude about how physics knowledge can be applied in everyday life. Although the ED group does not offer much information about the negative sides of the new method, the problem of applicability of this type of teaching regarding the abstract areas of physics (that are taught in the final year of high school) is noticed. They also consider that the reorganization of physics teaching through the new method is necessary.

There is a significant amount of dispersion among students of the RPQ group when choosing the teaching method that would realize the overall teaching of physics. The new teaching method – *Learning physics through reading, presenting and questioning* (RPQ method) is perceived by a significant number of students as a method that suits their needs. However, a great number of students emphasize the inability to cope with the new teaching method because of large amount of information, highly specialised terminology and the inadequacy of the teaching process. Thus, they choose the traditional teaching method. The combination of the traditional and the new method is chosen by a significant number of students. From the traditional and the RPQ method they choose what they believe to be useful for them: freedom of (non) participating in the teaching process, attractiveness, thinking encouragement and the subject matter accessibility. As far as the RPQ group is concerned, there is no difference in the choice of the teaching method depending on the group of thinkers. Regardless of the level of the students' scientific reasoning, the students are able to recognize both good and bad sides of the new teaching method and they do not perceive it as the exclusive physics teaching method.

Situation is significantly different with the group that uses *Learning Physics through Experimenting and Discussion* (ED method). Most students of this group would choose this method as the only way of learning physics. All concrete thinkers consider this method to be useful for their physics learning and that result is a significant success. Obviously, by participating in the new teaching/learning method they recognise the accurate thinking process, attractiveness of physics' topics and the self-efficacy. The teaching process in which active learning is promoted suits the students as the method of learning physics that results in communicating and acquiring knowledge. It is in harmony with the character and the needs of the young who develop through activity, attractiveness, thinking encouragement, application of physics knowledge in everyday life, and finally, through positive feelings during physics lessons.

This study has led to results and conclusions that could significantly improve the quality of high school physics teaching, students' interest in physics as a school subject and can also increase the number of students interested in physics and physics related careers. We would like to summarize a few potentially useful messages for teachers and researchers:

- The new methods of teaching/learning, as those two presented in this paper, are necessary in order to help the students develop the ability of scientific reasoning as well as deeper understanding of physics' contents.
- Successful physics teaching should aim at the students' progress regarding the concrete level of thinking.
- It is necessary to gain an insight in students' experiences and their expectations of physics teaching as well as to include them in successful teaching.
- It is recommendable to communicate more often with girls and create the conditions for cooperation activities that would motivate them to interact with male peers, challenge them and include them in active content learning.
- It is important to change the materials used in class activities in order to meet the needs of the students.
- Whenever possible, additional physics topics to the curriculum should be added to provoke the interest of boys and girls as well as specific types of students' activities.

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