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Physics Education Research in Croatia: Historical Roots and Actual Trends

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Abstract
Quality pedagogical tradition of Central European countries, in which the Croatian school system existed and evolved, helped in the establishment of the Department of Methodology of Teaching (in several disciplines) at the University of Zagreb and other Croatian universities (Split, Rijeka and Osijek). Unfortunately, it was not too long ago that Croatian physicists were still deeming teaching physics to be a profession that offers nothing for research. However, over the past twenty years or so, significant changes have been made in this field thanks to the hard work and the engagement of some researchers and groups. Here we will present the historical roots of Physics Education Research (PER), the results of PER trends and raising need of educating physics teachers in Croatia today.
Keywords: Physics education, curriculum, PER in Croatia

The beginnings of research-based physics curriculum in the Republic of Croatia

In the Republic of Croatia, the foundations for the principles of teaching physics have been set by Franjo Filipović. As the principal of "Izidor Kršnjavi" elementary school (in Zagreb), in the school year of 1948/49 he established the school as a place for training students from the College of Pedagogy who were preparing to become future physics teachers,. In 1968, Filipović published the book *"Primary school physics teaching methodology"* (Filipović, 1968), which was the first textbook for the methodology of physics teaching in this region.

During the 1970s, Prof. Dr. Gustav Šindler (Schindler) made a significant contribution to physics teaching. He obtained his PhD in Physics Education at the Charles University in Prague. He worked as a physics teacher in high schools in Sisak and Karlovac, and at the Teachers' College and at the Higher School of Pedagogy in Petrinja. As a full professor at the Faculty of Science in Zagreb, he conducted a course in physics education methodology. He published over a 100 professional and scientific articles, and authored several books, the most notable being *"Methodological basis for designing elementary physics teaching"* (Šindler, 1980) and *"Contributions to problem-oriented physics teaching"* (Šindler, 1990).

The most significant contributions to physics teaching and research of physics learning in Croatia were made by Prof. Rudolf Krsnik, who took over the course of *Physics teaching methodology* with all the pertaining seminars and teaching practice with students at the Faculty of Science (PMF) in Zagreb in 1984. He conducted the course until 2002, when he retired. After that, Prof. Krsnik continued his teaching activities as an associate collaborator until 2006.

In physics methodology he accepted and spread the ideas of educational constructivism wholeheartedly. Globally, that direction of both a philosophical and educational nature, was, in the 1980s, still in its initial phase, but evolved very much during the 1990s, becoming, at

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the beginning of the 21st century, a new paradigm for learning natural sciences. From 1984 to 2006, Prof. Krsnik introduced almost twenty generations of future physics teachers into constructivist methodology.

The impetus in the development and the connection of the physics curriculum at all levels were given by *The days of physics teaching* which have had, from the first (1993) to the tenth (2011) symposium, a constructivist orientation. Most of the credit should be given to Prof. Krsnik, together with a large number of Croatian physics teachers. He founded the first research group of physicists in Croatia (PMF, Zagreb) who dealt with the physics curriculum in a scientific manner.

As part of the methodological activities, he was the main organiser of an international summer school on physics curriculum, called *Recent Developments in Physics Curricula,* which was a great success (Crikvenica, 1989). He collaborated with researchers in physics teaching from the *King's College* in London, *the Institut fur Didaktik der Physik* in Karsluhe and *Sophia University* in Tokyo.

Prof. Krsnik was also the main organiser of the scientific symposium *The Croatian symposium of physics teaching*, which was first held during the homeland war in 1993 and was organised by *Teaching section of the Croatian Society of Physicists.* Ten of these symposiums were held from 1993 to 2011. What differentiates them from traditional seminars is the fact that most of the papers are presented by the instructors themselves, practically rather than theoretically, which motivates constructive discussion about the real problems of the physics curriculum and how they could be solved. This is also shown in the titles of the ten symposiums held so far:

(1) *Problems of updating physics teaching;*
(2) Contributions to the development of Croatian physics teaching curriculum;
(3) Perspectives of physics teaching;
(4) The role of experiment in physics teaching;
(5) Student – an active participant in physics classes;
(6) Problem and research-oriented physics teaching;
(7) Teaching physics for nature of science literacy;
(8) Interactive physics teaching;
(9) Teaching physics – achievements and challenges;
(10) The role of model and modelling in contemporary physics teaching.

The Croatian symposium on the physics curriculum proved to be very successful as a forum functioning in promoting the permanent education of physics teachers. It was a gathering of 250 to 300 participants on a regular basis.

From 1990 to 2002, Prof. Krsnik led a scientific project at the Ministry of Science called *Development of constructivist physics curriculum for elementary and high schools* and from 2002 a project called *Development and evaluation of constructivist physics curriculum*. These were the first scientific projects related to the methodology of natural sciences in Croatia.

Prof. Krsnik published the book *"Contemporary ideas in physics education methodology"* (Krsnik, 2008) which became a part of the fundamental literature for the physics education methodology course at Croatian Universities. It was based on the contemporary ideas developed in the West in the 1970s. According to that issue's development in modern countries, interactive education of physics is suggested, based on the ideas of educational constructivism. Its main points are that knowledge cannot be transferred

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to a passive recipient and that every person achieves personal knowledge via constructive and mental processes. The curriculum comes down to designing problems in whose solving the students actively engage in and achieve personal knowledge.

Physics education groups and research on physics learning in Republic of Croatia

The most important physics education groups in the Republic of Croatia are located in Zagreb, Rijeka, Split and Osijek (**Figure 1**).

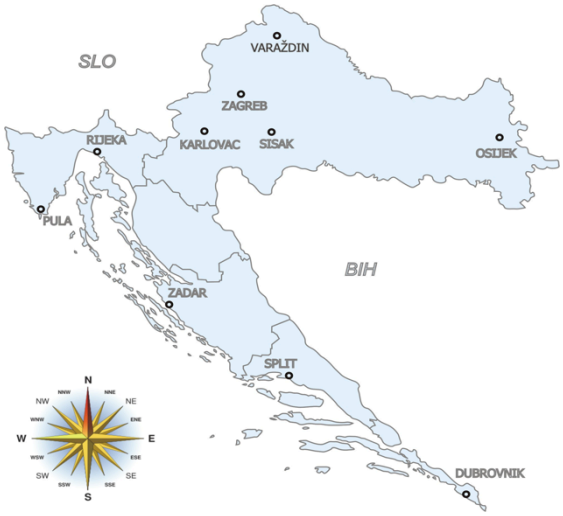

Figure 1. *The map of Republic of Croatia*

Physics Education Group in Zagreb

The work of Prof. Krsnik on the program of physics teaching principles was continued by Dr Maja Planinić, who studies various ways of the improvement of physics learning and teaching. She focuses her research attention on the preconceptions of the students and their effects on conceptual understanding of basic physics terms. The group for the methodology of physics teaching at the PMF in Zagreb have been working on a project named "Educational research in physics and mathematics" since 2006 (leader Dr. Maja Planinić), which was funded by the Ministry of Science, Education and Sport. This project consisted of multiple diagnostic researches conducted in Croatian physics classes, which can significantly help understand the problems students face when learning physics, and also provide information about the conceptual understanding of the terms which students learn while studying this way. This information has also been vital for introducing the national high school graduation into Croatia. Besides these diagnostic researches, some interactive teaching methods are being tested, too. Educational research of the problems students have regarding mathematical concepts and skills is of great importance for the further teaching of both mathematics and physics.

Although many typical misconceptions that students have about physics concepts and phenomena are already well known worldwide, in Croatia that wasn't the case. The group in the methodology of physics teaching in Zagreb started research in 1999/2000 and its purpose was to prove the existence of misconceptions and their permanence despite of many years of formal physics teaching. They also wanted to research the possibility of the comparison of misconceptions in various fields of physics, and see what effects that had on the teaching of physics. There were a total of 216 examinees, of which 59 % were male and 41 % female.

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The research was conducted at the end of the 1999/2000 school year and proved the existence of a variety of misconceptions that students hold, which makes it harder, sometimes even impossible, for students to accept new ideas in physics (Planinić, Krsnik, & Pećina, 2001).

In 2005, the applications of FCI (Force Concept Inventory) test were initiated. The people who first completed the test were a group of a Croatian high-school seniors, a total of 90 of them. Most of the seniors scored 30 – 40 % on the FCI test, 9 above 60 %, and none above 80 %. Even thought the entire population can't be judged according to a single school, these results are still worrying because they give an idea of how the Croatian physics is failing to develop a conceptual understanding (Planinić, 2005).

In 2005 Professor Mirko Planinić reported an interesting research that used ‘‘Peer Instruction". In order to apply this method, a group of freshmen were chosen from the field of physics. At the beginning of the semester, a test in mechanics was carried out to get an idea of conceptual understanding in this field. The average score on the test was 58.3 %, which listed the group as one of the best that was tested from PMF in Zagreb. During the semester, labs from general physics consisted of tasks to which conceptual questions were added. The method of "Peer instruction" proved to be a real success, improving the conceptual understanding of mechanics with an average score of 78.9 % on the test that was given after the semester (Planinić, Mirko, 2005).

In the school year 2006/2007, a nation-wide research on the conceptual understanding of mechanics was carried out with high school graduates (Planinić, Ivanjek, Sušac, Pećina, Krsnik, Planinić Mirko, Jakopović & Halusek, 2007). The sample consisted of 1,676 seniors (13.6% of the population), of which 429 seniors were from a Science High School, and 1,247 seniors were from General, Language and Classical High Schools. A total of 38.5 % of examinees were male, and 61.5 % female. 54 high schools took part in the research from all over Croatia, which represented 36 % of all high schools. Results showed a moderately low score among Croatian high-school seniors on the FCI test. The average score of the test (27.7 %) and the average score of two more groups was a lot lower than the threshold of 60 %. A total of 4.7 % students scored over 60 % and only 1.2 % over 80%. Results of the students from Science-Mathematics High Schools (36.2 %) were somewhat better than those from the ones from General, Language and Classical High Schools (24.8%), but still worse than expected. No significant differences were found between the students belonging to different geographical regions (Planinić et al., 2007).

For several years, the group in the methodology of physics teaching has already been carrying out pre-testing and post-testing of freshmen from the Physics-Mathematics Faculty in Zagreb via diagnostic tests in conceptual understanding of physics. Most students achieved moderately low results in both types of tests. Because of that, there was an attempt to change the type of teaching from classical lecturing to interactive lecturing for freshmen in teacher training studies. The aim of such a change was to determine the moderation of conceptual understanding of mechanics, electricity and magnetism. Exams were held at the beginning and the end of every semester, before and after lecturing mechanics, electricity and magnetism. The conceptual content of the courses "Physics 1" and "Physics 2" remained the same, but there were some modifications of the teaching methods. The amount of material that was processed during lecturing was reduced, and conceptual questions were introduced. The biggest change was made in the exercises: the classical method of solving tasks on the board was completely abandoned. Instead, the students solved tasks, discussed conceptual questions and problems in groups, following the tutorials developed by the PER group at the University of Washington. The use of interactive teaching methods in the courses of "Physics

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1 and 2" in PMF in Zagreb showed very satisfying results regarding the conceptual understanding of mechanics, electricity and magnetism students developed (Ivanjek, Planinić, & Sušac, 2009).

During 2010, this group carried out a research regarding the students' understanding of atomic spectrums. A total of 9 half-structured demonstrative interviews were carried out with the students in the higher years of physics program in Zagreb. Based on the results of the interview, pre-test questions were constructed, which were given to 400 students at the University of Zagreb and the University of Washington in Seattle. Results showed a necessity for improvement in lecturing and the development of new lecturing materials (Ivanjek & Planinić, 2011).

Physics education group in Rijeka

At the University of Rijeka, in the Department of Physics, a group also works in Educational Physics under the leadership of Professors Branka Milotić and Rajka Jurdana-Šepić. In the last few years, this group of scientists strengthened scientific and professional work in educational physics. In that field, they have been engaged in the development of concepts in Physics and interest in Physics for children, especially those of a "pre-Physics" age, and also in the development of educational modules intended for *"f2f" ("face to face")* student`s environment and e-learning, with the help of computers (Rajka Jurdana-Šepić, project *"Development and modelling of physical concepts in classroom and e-environment",* 2007).

In 2001, the Department for Physics designed and organised a new kind of electronic and laboratory exercises in Physics classes. These learning tasks are based upon the simple phenomena from everyday life, which students meets and accept *a priori*, but are unable explain using physics concepts (Kotnik – Karuza, 2001).

Rajka Jurdana-Šepić and Branka Milotić published an important manual *"Methodical physics experiments"*, in which over 120 methodically developed experiments were presented, intended for the teachers of Physics, as well for the students. Experiments are carried out with simple means and equipment, but they often have complex explanations and permit pose deep conceptual questions. Another important quality of this book is the modern, methodical approach based on constructivism vision of physics learning (Jurdana-Šepić & Milotić, 2002).

A group of researchers from Rijeka in 2001 studied the success of the Physics classes in primary schools and high schools in Primorsko-Goranska County. In spite of a positive attitude towards Physics expressed by most students who were included in the research, 86 % of primary school students looked for help outside the school to master the subject matter, while tutoring in Physics was taken by 33 % of grammar school students. 196 students were questioned about the problems and attitudes towards learning physics. The results show students attitude towards: Physics (67 % positive), lecturer (60 % positive), experiment (87 % positive), contents (51 % have objections), lectures (59 % support passivity), frustrations (50% of the cause is examining the knowledge), written exams (62 % positive – objective), using a text book (47% use text book on their own), additional help (84 % looks for help, and even 86 % in the 7th grade after only 13 classes of Physics) (Branka Milotić, Rajka Jurdana-Šepić, Manda Švabić, Zvonimir Peranić, 2003).

In 2003, Rajka Jurdana-Šepić and Branka Milotić organized workshops with the aim of creating part of a methodical practicum for the students in the teacher training course at the Department of Physics where an university professor and students could together and

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interactively teach primary and high school students and in direct contact with them could keep track of development and the formulation of primitive student concepts to the conceptual understanding of contents (Milotić & Jurdana-Šepić, 2003).

As part of a project *"Experiments in developing physical models and concepts"* from 2004 and 2005, with the joint work of professors of methodology and students of teacher training courses, they developed the educational contents for constructivist workshops for students of primary schools and high schools. The very base of the workshops was a set of 20 to 40 simple physics experiments, which were carried out with easy-to-find means, available in every household. One of the workshop`s purposes was to encourage children to repeat these experiments by themselves in their homes. New Physics workshops have also been created, and already existent workshops have been installed in web-form, as a part of the e-school of the Croatian Physics Society (HDF) (Milotić & Jurdana-Šepić, 2005).

Since 2004, the association *"Golden Section"* has been active in Rijeka with the purpose of which is to develop and improve Mathematics and Sciences classes. Until now, the association`s main projects were the organization of the international conference GIREP - EPEC 2007 in Opatija, and the long standing successful organization of the Science Festival in Rijeka (Jurdana Šepić, Milotić, & Žuvić – Butorac, 2009).

Physics Education Group in Split

The Physics Education Group at the Faculty of Science and Mathematics (PMF) at the University of Split, under the academic guidance of Professor Ivica Luketin, work together with the Education and Teacher Training Agency in Split on the constant improvement of pedagogical content knowledge of physics teachers in both primary schools and high schools.

In that work, important credit goes to Professor Mladen Buljubašić, who presented interesting diagnostic research on understanding of the law of conservation of energy and power in 2003. The research was done with 15 classes in 10 high schools. 400 students were included in the exams. The results showed that students had difficulties with some problem solving and conceptual tasks. The physics topics, which seemed easy to the physics teachers, on the other hand, were not easy for the students. One of the main conclusions was that with the simple, and small, fast experiments with inexpensive equipment, the student could be encouraged and also more involved (Buljubašić, 2003).

At the national seminar on Physics Education in 2008, members of the Department of Physics of PMF-Split surveyed 128 physics teachers, who evaluated, with a very high percentage, that the educational programmes in teaching training courses at colleges were inadequate as a preparation for physics teaching jobs in primary schools and high schools. Most of them are also dissatisfied with working conditions, both logistic and financial, and the fact that they did not have enough time to prepare experiments and innovations in class with 22 regular obligatory school contact hours weekly (Sokolić, 2009).

Physics Education Group in Osijek

By the decision of the Senate of Josip Juraj Strossmayer University of Osijek in 2004, the Department of Physics was established. This Department of Physics tested students understanding of kinematic graphs with TUG-K test in 24 high schools in Eastern Croatia, at the end of 2007. 1,169 high school students in the first year were a part of it. This research confirmed the original assumption about the difficulties that students have while interpreting and understanding graph samples of the basic kinematic themes (Radolić & Blažević, 2009). The biggest problems that students had were those with interpretation of the slope of the

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graph and the area under the graph in physics. Similar research was done in Zagreb and in Slunj (Department of Physics and Mathematics, PMF-Zagreb) and in Rijeka (Educational and Teaching Training Agency) in 2008, and drew the same conclusions.

The implemented check which had been carried out about the conceptual understanding of electromagnetism with the CSEM-test (*Conceptual Survey of Electricity and Magnetism*) with 490 students of Electrical Engineering, Computer Science and Food Technology at the University of Osijek showed that the students of Electrical Engineering and Computer Science, while learning basics of Electrical Engineering, learned well the main concepts of electricity and magnetism. The success in the pre-exam of Food Technology students was very poor, which could lead to the conclusion of insufficient knowledge and understanding of contents from electromagnetism during high school education, but also on the missing of both inner and outer motivation for solving this type of test. In spite of significant differences in the ways of teaching these physics contents, the overall success of student of Electrical Engineering, Computer Science and Food Technology at the University of Osijek is very similar to the overall results of the original American research, as well as the earlier carried student research in Croatia (Miokovic, Ganzberger, & Radolić, 2012).

Studies of physics learning and teaching in other departments of physics

Besides their activities at the Department of the Methodology of Teaching Physics at four Croatian Universities, departments of physics are a part of many other higher education institutions and their activities have been directed to explore learning and teaching of physics. The main results of these studies are presented here.

It is interesting to observe the research that the Institute of Physics and Biophysics of the Faculty of Medicine of Zagreb made in the year 2003, which presented the success of high school students in the entrance-examinations, which consisted of easy questions in physics. The results showed that only a quarter of prospective students understood the basic laws of physics. Unfortunately, 70-80 % of tested students showed little or no understanding of the basic principles of physics, necessary for the further education of (Dolanski Babić, 2003).

Besides this study, the Department of Physics and Biophysics of the Faculty of Medicine of Zagreb carried out an analysis of the success of the physics and biophysics exams carried out at the Medical Faculty of Zagreb, in the period between 1999 and 2003. Research results showed that only a few students from medical high schools enrolled. It's not so much a consequence of lack of interest, but it is probably due to poor results in entrance exams. As evidenced by the overall evaluation of the exams, students from other high schools (technical, economic ...) come with a higher knowledge of physics, than students who attended medical and mental health schools. Students who had completed High School did not gain significantly higher physics exam scores than those who completed vocational school, especially when compared to the results from Zagreb High School (Kirilov, 2003).

The Department of Physics at the Faculty of Medicine in Zagreb together with the Faculty of Science at the University of Zagreb (PMF) reported a study, done in 2005, in which they used simple physics tasks to examine students' alternative conceptions. Total of 1,174 first-year university students were examined at universities who had physics as a part of the entrance exam. Students of the Faculty of Science were not examined. It appeared that:

- Knowledge of problem solving was not an indicator of understanding of physics.
- Students did not see either consistency or logic in physics.

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- Students did not connect the laws of physics with their personal experience and with real life as well.
- Differences in the students' answers from different faculties were not markedly significant.
- Type of completed high school did not significantly influence the accuracy of responses.

It was found out that many students' alternative ideas arose from physics lessons. Physics lectures failed to present physics as a consistent and logical science related to everyday life (Balarin & Pećina, 2005).

A written examination has been taken to examine students' achievement in physics learning at the Department of Physics of Faculty of Medicine of the University of Rijeka. Such a form of knowledge evaluation has been used for many years at entrance exams to the Medical Faculty of Rijeka, and recently in written examinations in medical physics and biophysics. The results of 398 candidates admitted to the entrance examination for university studies at the Faculty of Medicine in July 2004 were analysed. It was evident that the poorest result, among all candidates for all of the university studies on the Faculty of Medicine, was achieved in solving problems in a part of the exam, which consisted of questions from physics. It was concluded that secondary school students should get acquainted with different types of written tests of physics. The amount of questions that check the content understanding should be as large as possible, but should not insist on solving the numerical problems only (Žauhar, Lekić, & Mandić, 2005).

In 2005 the results of a research, conducted by the Institute of Physics of the Faculty of Medicine of Rijeka, and the Department of Physics and Environment of the Technical Faculty of Rijeka and the Department of Physics of the Faculty of Philosophy of Rijeka, were presented. The aim was to find out the extent of the correlation between students' achievements in physics and an individual learning approach, especially in the part, which occurred outside of classes. An anonymous survey that examined the attitude towards physics and methods of physics learning was applied to 644 students of Rijeka Comprehensive School. The correlation between the success in physics and individual learning approach was illustrated by following facts: 65% of students regularly learned physics, 71% of the students learned it during the lesson, and 72% communicated with the teacher when difficulties arise. It is demoralizing to find out that tutoring in physics were taken by only 33% of comprehensive school students and it is explained as "the fastest way to prevail the teaching material". Besides, the presented results called the attention to the problem of the teaching process of physics, teachers of which should have changed their teaching methods in order to increase active learning and teaching students in methods of how-to-learn physics (Mandić, Mandić, & Jurdana-Šepić, 2005).

The research of students' attitude toward experiments in physics has been carried out by the Department of Physics of the Faculty of Medicine of the University of Rijeka. The survey included 251 students in the first academic years of 2005/2006 and 2006/2007 in General Medicine studies. As shown by the results, the majority of respondents, 47.5 % experienced the theoretical exposition as the prevailing teaching method. 23.9 % of the total number of students mainly experienced numerical tasks, and 28.2 % of students in physics classes experienced balanced demonstration of the physics theory combined with figuring out a problem and experimenting. Out of the 80.7 % of students who experienced experiments during previous schooling, 53.1 % of them stated that the experiments were performed by the teacher, then 44.9 % of the experiments were performed by both teachers and students, while

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in only 2 % of cases students performed experiments independently. The majority of students (60.7%) preferred performing physics experiments, while 72.2 % of students had a positive attitude towards the Physics Practicum (Bojić, Mandić, & Lekić, 2008).

Within the last five years, the (teachers) employees of the Department of Physics of the Faculty of Graphic Arts of the University of Zagreb have presented the results of physics examinations showing that prior knowledge of students lessens, and that it is difficult to perform the high-quality university level in teaching physics. As an example, the authors reported that no one, among 180 participants at the first mid-term exams in Physics 1 in the 2010/2011 academic year, passed the mentioned exam even though the tasks were of the same type as they were on the state matriculation exam. (Modrić, Džimberg-Malčić, Petrić, Maretić, & Itrić, 2012)

New technologies in physics teaching and learning

A part of important discussions and scientific studies in recent years in the Republic of Croatia includes the introduction of new technologies in physics teaching. Its authors Buljan and Pećina presented the development of an interactive on-line textbook, which enables better understanding, and improving of knowledge. They conceptualised the testing of knowledge and understandings as games of connecting and memory, but required the students to actively use the obtained knowledge (Buljan & Pećina, 2003; Buljan & Pećina, 2005).

The Physics Department of the Chemical Engineering and Technology College of the University of Zagreb has conducted research on how many students have access to the internet, how many use the internet in search of knowledge and data of physics, if they read scientific-popular literature and what the role of textbooks is in today's school reality. That is equally interesting in the first years of technical studies, where general physics is taught. The survey included 146 students in the first year of technical colleges of Zagreb University, of which 72 were from the College of Chemical Engineering and Technology (FKIT) and 74 from the College of Electrical engineering and Computing (FER). Textbooks were used by 25% of elementary students and by 35% high school students. The others rarely or never used the textbooks. The survey also revealed that the first year students (also last year students of high schools) in general have internet access and search opportunities, but they haven't been motivated to search physics related data. It is also noted that amongst students exists significant interest in reading popular-scientific literature, which in recent times is present in Croatian translation as well (Lopac, 2003).

In the year of 2005 positive experiences with the programme Pintar Virtual Lab were presented. It was intended to perform virtual experiments in different domains of physics such as electricity, optics, electronics, mechanics (Bubnjar & Bubnjar, 2005).

Experience with the computer programme Tex-Sys in physics classes has also been positive. Students with the help of Tex-Sys learn with a greater amount of pleasure, they learn more often, get more feedback on the acquisition of knowledge. They also can determine the depth and the speed of learning themselves. (Paić & Plavičić, 2009).

Other research related to physics learning

Besides the Physics and Physics Methodology Department, there are teachers of physics in the Republic of Croatia who do significant research on physics in education. We will present the most important results of their research and some researches done by the Education and Teacher Training Agency whose goal it is to improve classes.

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The report about the research of the evaluation of constructivist physics classes was presented in 2005. The constructivist physics classes were evaluated by exploring understanding and students' attitude among 8th-graders in elementary schools in Rijeka, Pazin and Zagreb. The students were divided into groups that were practising constructivist classes of physics only, and those who were practising physics in a traditional way. More than a quarter of students are motivated by the teacher and constructivist teaching, and only a tenth by traditional teaching. (Peranić, 2005.)

Svedružić carried out an interesting research whose results were presented in 2009. This research answered the question whether there was a difference in the understanding of basic physical terms when an interactive and a traditional demonstrational experiment was applied. This research showed that the effect of the demonstrational experiment is significantly contributes to general and conceptual understanding of physical terms when students set hypothesis and discuss them, create an experiment, check the hypothesis and make a conclusion (Svedružić, 2009).

The same author carried out research whose goal was to check to what measure elementary students, high school students and university students of physics understand the nature of science and scientific research. 150 examinees participated in the research. The procedure of evaluation was carried out with SUSSI (*Student Understanding of Science and Scientific Inquiry*). It was shown that there was a modest proportion of students who had correct attitudes when it came to scientific theories and scientific laws, the effect of society on scientific research, the effects of human imagination and creativity in science and science methods. The student population showed deficient understanding in the nature of science with regard to the view of the effect of the society on science and the distinction between scientific theories and laws. (Svedružić, 2009).

In 2007 Damir Rister studied attitudes of students and teachers about physics classes in elementary school before HNOS (Croatian National Educational Standard). The research was done by the researchers of the Centre for research and development of curriculum, during April and May in 2003, in 121 elementary schools in the Republic of Croatia (approximately 15% of schools). A total of 2,674 students and 2,134 teachers were questioned, 77 of them were physics teachers.

On the basis of the research, it can be concluded that students don't like physics as a school subject. For the majority of students, physics is incomprehensible and uninteresting, and only 3.7 % of students think of physics as their favourite school subject. Students don't think that physics can be useful neither in this contemporary life nor in their future. On the scale of the least popular school subject, physics takes the third place, right after chemistry and mathematics and mostly because of the difficulty and incomprehensibility. Physics as school subject is extremely unpopular with the girls who, in all aspects, evaluate it more negatively than the boys. Research has also shown that there are certain weaknesses among teachers. First of all, there is the use of new technologies and adjustment to the language of new generations. Teachers emphasise the need of professional specialisation and the necessity of comprehensive and demanding changes within the physics programme and a significant increase of experiments and laboratory exercises (Rister, 2007).

In 2007 a report about the research of solving non-traditional physical problems followed the 8th graders and students of teacher majors in physics were tested. The results showed that students in elementary school and those in university were glad to solve a non-traditional problem and that they actively participated in the discussion of the solution after the survey. The conclusion is that problems from everyday life should be solved more often. (Pećina, Sliško, 2007). The research into students' capabilities in solving a partially specified

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physics problem was carried out on 50 high school students and 50 students of the 4th year in FESB (Faculty of Electrical Engineering, Mechanical Engineering and Naval Architecture), Split. The results show that commonly formulated numerical exercises are not sufficiently developing the capability of critical thinking (Erceg, Marušić & Sliško, 2011; Marušić, Erceg & Sliško, 2011; Marušić, Erceg & Sliško, 2012).

Marušić and Sliško studied, with 176 high-school seniors, the learning outcomes of two new interventions in high school physics teaching within additional school activities: Reading, presenting and questioning (RPQ method) and Experimenting and Discussion (ED method). For the first time in the Republic of Croatia, a quantitative estimation of efficacy of these two interventions was realised with Lawson's test of scientific reflection (LCTSR) and the CLASS test (Colorado Learning Attitudes about Science Survey). One-semester's data showed that by the RPQ method an average normalised gain on Lewis test was achieved <G> = 0,19, while the ED method caused a <G> = 0,32 (Marušić and Sliško, 2012a; 2012b). Special attention was dedicated to the progress of students who were concrete thinkers. This progress towards a higher level of thinking was gained by 43.5 % of students with the ED method or 25.0 % with the RPQ method. The CLASS test results showed that both methods improve students' attitudes, but with different grades. With the RPQ method a total increase of only 5.8 % in attitudes and convictions was gained, while by the ED method an increase reached a respectable 25,6 % (Marušić and Sliško, 2012c). These results indicated that both methods could have a significant potential for the improvement of students' attitudes and convictions about physics and the learning of physics, with the emphasis on the ED method.

Education and teacher training agency (AZOO) tested 1093 students of the first 40 high school classes with a FCI test in Croatia. The research was done in 2007/2008. The results showed problems of students in conceptual understanding of mechanics, which are similar to the ones in other countries where the FCI testing was held. Just a bit above 10% of high school 1st graders crossed the threshold of Newton reflection after learning mechanics and entered an area of conceptual understanding of mechanics (Jakopović, 2009). Also, the results showed that student understanding of mechanics was positively connected with the representation of the method of discussion and the method of researching physical phenomena with experiments and with the representation of evaluation of questions during experiment performances (Jakopović, 2012).

Projects in physics teaching

In the Republic of Croatia, throughout the physics teaching, some significant projects have been made. Here come the most significant examples.

The GLOBE programme is concerned with measuring and observing in nature. The basic measurements and observing factors are: atmospheric, hydrological, geological and biological measurements and observations. The practice of the GLOBE programme indicates the PC and Internet possibilities with students. (Trlek, 2001). After 15 years of implementation in Croatia the GLOBE programme was involved in about 140 schools, therefore by the percentage of schools involved it is among the first in the world. Thereby, Croatia has acquired exceptional reputation and sympathy in the world's GLOBE network.

The project of web textbooks and web practicum for the students of medicine and dentistry is a project that got support from the Ministry of Science and Technology and was presented at the INFO 2000. (Gamulin, 2001).

Project GEA is an educational-scientific project designed in Primary school Marjan-Split, and it was carried out through cooperation with PMF in Split with the support of the

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Ministry of Education and Sports and the support from the Professor Vladimir Paar. The goal of project GEA was to enable gifted children from elementary schools to obtain modern scientific knowledge and develop of a research approach to fractal geometry and theory of chaos, through watching nature and by applying modern techniques and technology (Stanić, 2003).

Problem-solving and research-oriented teaching of physics in the Technical school of Ruđer Bošković - Zagreb is the base of a project which is made up from student research, professional visits to individual institutes, the Technical museum and the Nuclear power plant "Krško". Student research, occurring when the conditions were met, was carried out through independent experimental measurements, with mentoring of their teachers, and sometimes with support of physicists from PMF (Ilić, 2003).

Project PHYLAB.NET represents an Internet page the development of which can be followed on the web address: http://www.phylab.net. Physicists from the 1st Technical School Tesla in Zagreb, with cooperation from former and current students, started the page. The page is made from a section for students, a section for physics teachers and a common section (Njegovec, 2003).

Physics Education Project Portal of Croatian physics society represents a web page the development of which can be followed on the web address: http://nastava.hfd.hr. The project is an interactive page, meaning it's a place developed for the exchange of information between physics teachers in general. Furthermore, the page strives for connection with already existing content on the Internet like E-school physics of HFD, sites of the Institute for Education and the Ministry of Education etc (Njegovec, 2005).

The sky as a gift is a project that started in 2004. The project was applied on students at the age of 10 to 15 years. Until today this project has had 1,801 students (from 4th to the 8th grade of elementary school) and 182 teachers who finished training to conduct an astronomical observing group (Bedalov, 2009).

Publications in journals

In the Republic of Croatia a relatively small number of scientists, dealing with students' physics learning, have published their works in international journals, which are included in ISI Web of Science.

The members of the group for methodology of physics teaching from Zagreb published three papers:

1. Planinić, M. (2006). Assessment of difficulties of some conceptual areas from electricity and magnetism using the Conceptual Survey of Electricity and Magnetism. *American Journal of Physics*, 74 (12), 1143-1148.
2. Planinić, M., William J. B., Krsnik, R., & Meredith, B. (2006). Exploring Alternative Conceptions From Newtonian Dynamics and Simple DC Circuits: Links Between Item Difficulty and Item Confidence. *Journal of Research in Science Teaching*, 43(2), 150 - 171.
3. Planinić, M., Ivanjek, L., & Sušac, A. (2009). The Rasch model based analysis of the Force Concept Inventory. *Physical Review Special Topics - Physics Education Research*, 6(1), 010103

Nataša Erceg and Mirko Marušić, who are working on their doctoral projects in educational physics at the University of Sarajevo, published the following papers:

1. Marušić, M., Erceg, N. & Sliško, J. (2011). Partially specified physics problems: university students´ attitudes and performance. *European journal of physics*, 32(3), 711–722.
2. Erceg, N., Marušić, M. & Sliško, J. (2011). Students' strategies for solving partially specified physics problems. *Revista Mexicana de Física E*, 57(1), 44–50
3. Marušić, M. & Sliško, J. (2012). Influence of Three Different Methods of Teaching Physics on the Gain in Students' Development of Reasoning. *International Journal of Science Education,* 34(2), 301– 326.
4. Marušić, M. & Sliško, J. (2012). Effects of two different types of physics learning on the results of CLASS test. *Physical Review Special Topics - Physics Education Research*, 8(1), 010107-1 - 010107-12.

Four articles, which do not report results of research on students' learning but are related to physics teaching, have been published in following international journals:

1. Jurdana-Šepić, R. (2005). Rijeka' s 2005 Science festival attracts an enthusiastic crowd. Physics education, 40 (4), 302-302.
2. Labinac, V., Erceg, N. & Kotnik-Karuza, D. (2006). Magnetic field of a cylindrical coil. American Journal of Physics, 74 (7), 621-627.
3. Plavčić, M., Županović, P. & Bonačić Lošić, Ž. (2009). The resonance of the Wilberforce pendulum and the period of beats. Latin-American Journal of Physics Education, 3 (3), 547-549.
4. Aviani, I. & Erjavec, B. (2011). An easy method to show the diffraction of light. Physics education, 46 (2), 134-135.

Some researchers in the field of physics learning and teaching have published their papers in Croatian journals dealing with education:

1. Jurdana-Šepić, R. & Milotić, B. (2004). Physics teachers in their education and teaching experience. *Napredak*, 145(2), 223-230.
2. Jurdana-Šepić, R. & Milotić, B. (2005). Communication perpetuum mobile in physics teacher education. *Metodički ogledi*, 12(1), 19-24.
3. Svedružić, A. (2005). Creativity and divergent reasoning in science teaching. *Metodički ogledi*. 12(2), 103-118.
4. Svedružić, A. (2006). Evaluating the efficiency of computer assisted physics teaching in primary schools. *Odgojne znanosti*, 8(2), 535-549.
5. Svedružić A. (2007). Scientific curriculum in STS paradigm. *Metodički ogledi*, 14(2), 101-116.
6. Svedružić, A. (2008). Demonstrational experiments in physics teaching. *Metodika*, 9(2), 337-344.
7. Svedružić, A. (2009). Various aspects of nature of science in contemporary physics teaching. *Metodički ogledi*, 16(1-2), 113-142.
8. Marušić, M. & Sliško, J. (2009). Are there "male" and "female" attitudes about physics learning, about physics as science and about physics as a profession? *Metodički ogledi*, 16 (1-2), 87 – 111.

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The Education of Physics Teachers

In the Republic of Croatia, education of physics teachers is performed at four universities. Those are the University of Zagreb, Rijeka, Split and Osijek. At PMF Zagreb University, there are 4 programmes: educational physics, educational mathematics and physics, educational physics and chemistry and educational physics and technology. The Physics Department at the University of Rijeka organises studies for educational physics and mathematics and educational physics and computing. At PMF Split University there are studies for educational physics, educational mathematics and physics, educational physics and computing and physics and technology. At the University of Osijek study for educational mathematics and physics is organised.

The teacher of physics in elementary school, high school or university had no place for further scientific progress (except in some recognised disciplines of physics in which the methodology of teaching physics wasn't included).

Although among teachers of physics, as well as among the significant part of academic public, there is a wish for introducing doctoral study for educational physics, the realisation of that project still hasn't been done at any of the Croatian universities.

The only positive example happened in academic years 2003/ 2004 and 2004/ 2005. In those years graduate study of "Didactics of natural sciences" was organised at the Faculty of Science and Mathematics and in educational areas of the University of Split (later the Faculty of Sciences, Mathematics and Kinesiology, now the University of Split, the Faculty of Science and Mathematics). The study had three programmes: Physics, Chemistry and Biology and it allowed students to acquire the Master of Science Degree. Unfortunately, this study stopped working very soon.

The University of Split, The Faculty of Sciences and Mathematics is actually planning on running postgraduate university study *"Researching the education in the areas of natural and technical sciences"* in 2012. This program is going to be organised as the study for acquiring the Master of Science Degree. It is performed through research and teaching classes. The teaching programme includes, besides contemporary content from substrate science (the area of natural and technical sciences), contents from social-humanistic sciences and an overview of research in teaching classes of certain professions (professional methodology) as well. The program has the following sub-programmes: Biology, Computing, Chemistry and Technology. It should be emphasised that this will be the first doctoral programme for teaching of natural sciences in which, unfortunately, Physics won't be included.

Due to the impossibility of further education concerning methodology of physics teaching, young people have to find their ways outside Croatia. The example for this is Prof. Zdeslav Hrepić who went to the USA, obtained a PhD in Curriculum and Instruction and now works at Columbus State University (USA), making significant contributions to PER (Hrepic, Zollman & Sanjay Rebello, 2007; Hrepic, Zollman & Sanjay Rebello, 2010).

Conclusion

In the Republic of Croatia, a relatively small amount of educational research in physics has been done. This research is mostly diagnostic. At the same time, there is a disproportion between what has been published in international journals and the quantity of presented papers at national conferences on physics teaching. Still, the results of that research have led

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to introduction of a series of interactive methods for learning physics and to the significant number of projects in teaching.

Nevertheless, as national exams in Physics have been conducted, as Croatia has been involved in international research PISA, as the National Final Exam (Croatian: Državna matura) and studying under Bologna process have been introduced, the conditions and necessities for significant research on physics education have been created. For future research concerned with this, as well as for the improvement of quality of physics learning and teaching at all levels, the opening of a PhD program related to physics education research at one of the Croatian universities is necessary. It is hoped that Croatian physicists will understand these needs and that they will follow worldwide scientific trends concerned with research in physics education.

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