Olympiads in Informatics, 2018, Vol. 12, 53–68

DOI: 10.15388/ioi.2018.05

New Approach for Comparison of Countries' Achievements in Science Olympiads

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Abstract. There are several International Olympiads for secondary school students (for example, mathematics, physics, chemistry, biology and informatics). These Olympiads are not just a science competition, but a means to care for talent in the particular science.

The goal of this paper is to identify the necessary topics important for good results at these international contests, and to compare the contest systems for the countries in South Eastern Europe, in the field of Informatics (Computer Science), as a region that is one of the prominent world regions in the context of high results in the international competitions. Here, we provide comparison through detailed analysis of several countries, and further we present a new approach that may be used to compare the achievements of the countries based on the results that students achieved at these competitions. Finally, we present an application of this approach on the results of some of the discussed countries compared to Macedonia.

We strongly believe that the paper will provide a valuable content and approach for the entities involved in the organization of the contests, to measure their results compared to other countries, to use the information for improvement, and to use their achievements to raise awareness among the government institutions and companies in order to get support from them.

Keywords: students, STEM education, science competitions, programming.

1. Introduction

There are several International Olympiads for secondary school students, but five of them that are most widely recognized are those in mathematics, physics, chemistry, biology and informatics. Most of these were originally founded under the auspices of UNESCO (Taylor, 2012). These Olympiads are not just a science competition, but a means to care for talent in the particular science. Caring for talent involves a broad range of issues, including identification of talent and education adjusted to that talent (Verhoeff, 2011).

In particular, the International Olympiad in Informatics (IOI, 1989) is an annual programming competition, reserved for secondary school students. Students compete by solving problems (of algorithmic nature) in one of several available programming languages (C, C++, Pascal, and, as of 2015 – Java). In the last few years, participants received full feedback for their submissions, which wasn't the case with earlier Olympiads. The contest is usually organized in two competition days, and countries are limited to 4 competitors each (Kostadinov *et al*., 2015). The first IOI was held in 1989, and this year, the thirtieth Olympiad will be held (in Tsukuba, Japan).

In general, competitions are a major factor in education (Verhoeff, 1997). A lot of countries use different forms of competitions in order to encourage students to perform better in school (for example, in order to earn scholarships or grants), to bring the best out of them (by enrolling students into special programs based on their interests), or to promote cooperation by grouping students into teams and teaching them (through competitions) the importance of collaboration between people with different talents and preferences (Kostadinov *et al*., 2015). Whatever the goal, competitions must be fair in order to make them engaging for the participants. That is, each participant (student, team) should have the same chances, as possible, of winning. All science Olympiads try to satisfy this criterion.

The role of competitions in informatics is additionally emphasized in education, since the current status of informatics education is unsatisfactory in many countries (Guerra *et al*., 2012). Although computers, applications, and information technology (IT) in general are an increasingly natural part of the everyday work in schools, focus is mainly put on basic digital literacy skills, while the underlying principles are left uncovered. This situation has been recognized as a problem in many countries, and recently the introduction of computing in the curriculum (e.g. UK, Estonia) has resulted in an increased debate throughout Europe (Dagienė, 2014). Macedonia is one of the first countries that has also included Computing as a compulsory subject in the primary school curriculum (Jovanov *et al*., 2016).

Having in mind the importance of competitions, especially on international levels, each country has a specific educational system and different attitude and focus on them. This depends on many factors that include the base of teachers in the particular field, their dedication, as well as the dedication of the state institutions on the promotion of the competitions and their support. In some countries the main effort for the conduction of competitions is undertaken by private or non-government organizations or even by a few individuals.

In this paper, we will explain the strategies for good results at IOI (and IOI-like regional contests) in the next section, and then we will focus on the organization of the informatics competitions in selected countries from the South Eastern Europe (SEE) region, as a region that is one of the world's prominent regions in the context of high results in the international competitions. The analysis has been done through extensive interviews with relevant representatives from Romania, Bulgaria, Serbia, Montenegro, Slovenia and Turkey, who are involved in the organization of their competition cycles. Additionally, we include the situation in Macedonia, from our relevant experience. The findings will be summarized in a table that will allow quick comparison that may be used for further actions on the improvement of the effort in some country. This will be given in the following section.

Further, in Section 4, we will present a new approach that may be used to compare the achievements of the countries based on the results that students have achieved at these competitions, and in Section 5 we present an application of this approach on the results of the discussed countries, especially compared to Macedonia. At the end we present the conclusions.

2. Achieving a Good Result at an International Olympiad

To win a medal at any of the international science Olympiads, the student should really have great qualities, but that's not enough. ***Our experience in participating in competitions and recruiting successful competitors shows that several factors are important: quality education, gift, tradition, competitive environment, continuous work and quality training***.

For example, Macedonia has a much smaller population than most countries, and the number of gifted students is statistically much lower, so in order for a student to enter in the rank of medals at the international competitions, a serious commitment to each of these aspects is required. In the following subsections we will give our summarized knowledge and experience in the particular topics.

2.1. *Quality Education*

The educational system in one country plays a major role in its success at the major competitions in science. The first introduction to the basics of a particular area usually happens in schools. It is the place where the student realizes that he has the predisposition to understand the subject. The encouragement of students who are interested in some discipline is firstly made by their teachers in regular education and they are the ones who can judge whether a particular student stands out from the rest of the students in the given area. They are the first to give guidance to these students, to encourage additional activities and to develop their love for science.

2.2. *Gift*

The most important thing that a student should possess to be able to win a medal at an international Olympiad is an extremely great gift for science. According to the authors of one of the most prestigious books in algorithms (Cormen *et al*., 2009), to design and prove an algorithm is an art, so they call the development of algorithms "the art of designing algorithms". This is an important element especially when it comes to competitions that happen in a short period of life, such as programming contests, in which students have only 2–4 years to reach some level of knowledge that is needed for success. Therefore, here the student must be able to quickly learn new methods and techniques, to clearly perceive the problem in order to design a solution and to handle unforeseen situations easily. The scientific committees of international Olympiads, such as the IOI and IMO, prefer to separate students who possess extremely high logical intelligence rather than identify those who have learned the most number of techniques. They try to make original tasks that can be solved without the use of great theoretical knowledge.

2.3. *Tradition*

Countries with long-standing tradition achieve greater successes in international competitions, regardless of economic and political events or their size. A proof to this claim are the relatively small countries such as Bulgaria, Serbia and some former Russian republics, which have also won gold medals. Each new generation learns from the previous one and tries to surpass it, and even if it fails – the quality level cannot fall significantly, first of all because the standards are set to a relatively high level. Knowledge from an area in a given country is "a continuous smooth function", which gradually changes over time, so it is necessary to spend a few years for a greater decline or growth. And our results show just that.

2.4. *Competitive Environment*

Rarely can a student greatly differ in his knowledge and skills as compared to the students in his environment. Every student compares and competes first with the students of his own school, his city, and finally – with the students of his country. For each student, firstly it is most important to be selected for the international Olympiad team, and only after to achieve significant success at the Olympiad. So, when a student is aware that there is no competition in his/her environment, he/she will work much less. Hence, it is extremely important to create a larger group of students capable of achieving a good result in national competitions, so that they motivate each other to overcome one another.

2.5. *Continuous Work*

As in any other area, giftedness without work will not produce results. To win a medal at the Olympiads, one must work all year long. In informatics, students have the opportunity to participate in online contests organized worldwide.

2.6. *Strong Training*

One of the negative things about on-line competitions is that they last shorter than the contests at the Olympiads, and that some of the problems that need to be solved there are considerably easier. Sites rank the competitors, so it is important for them to solve as many tasks as possible. Therefore, organized preparations (training camps) should aim, for example, to change the students' approach of solving easier tasks in a shorter amount of time, to solving a difficult task in a longer amount of time. Of course, they also must get them to improve their programming skills.

2.7. *Specifics for the Macedonian Case*

In this subsection we will point out some specifics from our personal experience in Macedonia relevant for the topics above, which may put an additional light on the subject.

Our experience shows that there is a small number of teachers in Macedonia who want to work with their students additionally, who try to teach them above the standard curriculum and who are willing to participate in competitions and other events with their students. But does the problem lie only in the quality and commitment of teachers? In recent years, the government has introduced several measures that should encourage teachers to work more actively with gifted students, which include (financial) prizes for the results achieved at international competitions. But, the measures are not "attacking" the problem systematically, so we still lack results.

The lack of training in the regular school for informatics competitions transfers this problem to the Computer Society of Macedonia (CSM), as a non-government institution responsible for the participation at international Olympiads. Therefore, the trainings that CSM organizes include not only students that are selected for the international contests but also some other students who have shown great results in the local competitions (close results to those of the selected students). Also, CSM tries to send students to other international competitions outside Macedonia, including students who are not in the first team. The trainings that are organized by CSM are really strenuous and can last more than 10 hours per day.

In the following section we will present specifics for selected countries of the SEE region.

3. Current Situations in Selected Countries from SEE

In this section we will present our findings, based on reports, interviews and published papers, for the situation in selected countries.

Information regarding the situation with competitions in **Serbia** was provided by Jelena Hadzi-Puric, a professor at the Faculty of Mathematics, University of Belgrade.

The annual cycle of Serbian competitions consists of four levels: Municipal or online Qualifications, Regional, National Competition, and the Serbian Olympiad in Informatics (SIO). This year, around 750 junior contestants have been involved in the first level qualifications, and 1273 senior contestants tried to solve at least one problem. For the Regional and National competitions, students are divided into two divisions: A and B. Division A consists of contestants from schools that follow the program of a special high school for gifted students – the Mathematical Grammar School. All other contestants are included in division B. The main difference between the problems in these two divisions is their difficulty. Furthermore, the minimum number of points needed for advancing to the next stage can be different between divisions.

For the Regional and National competitions in Serbia, there is no global training. However, there are some online tournaments via the online judge system (Petlja, 2018). Furthermore, some special schools organize preparations, which vary from town to town. A training camp for the Serbian national team (for JBOI/EJOI or BOI/IOI) is organized every year. Most of the times, the training camp is organized in Belgrade or some mountain camp (Divcibare, Petnica), where students have lectures all day. The training is structured so that there are two basic modes of practice: 2 hours of theoretical lecture (on a blackboard) in the morning, and 4–5 hours of coding in the evening. Typically, this training lasts for 5 days.

As Hadzi-Puric explains, "Before 2016, we didn't have an official support for training camps. Our society, Mathematical Society of Serbia (DMS, 1948), had received a portion of the money from the Ministry of Education, but just to cover travel costs for an international Olympiad. In the last two years, the Ministry of Trade, Tourism, and Telecommunications organized a public invitation to all interested associations and foundations, having the status of non-government organizations, to submit program proposals for co-financing from the funds allocated from the budget of the Republic of Serbia. The subject of the invitation was granting funds (10 000 euros) for programs in the field of information society development, i.e. within the international competitions in the field of computer science, mathematics and physics."

According to Ranko Cabrilo, assistant director for IT at the Examination Centre of **Montenegro** (ECM, 2005), the annual computer programming competitions in Montenegro are organized in two levels. These are the School level competition and the State competition. Condition to qualify for the State competition is to win more than 50% of the total points in the School competition. Since in Montenegro, computer programming is an elective and not a regular subject in high schools (where most students come from), they don't have a huge number of candidates. Prior experiences state that the number of candidates is usually between 15 and 20. Most of the candidates successfully qualify for the State competition. The school competition is organized and financed by schools. All state competitions (including computer programming), from which students qualify for the Balkan and the International Olympiads, are organized by ECM. After the State competition, ECM organizes trainings for the best competitors, and it also covers the travel expenses for international competitions.

As Cabrilo explains, "it is difficult to estimate the budget for covering all the expenses regarding computer programming, as all competitions in various subjects are also financed as computer programming. These subjects include Mathematics, Physics, Chemistry, Biology, Geography, etc." In any case, if there is shortage of assets, ECM tries to include different sponsors and donors in order to smoothly organize all competitions and travels.

The competition cycle in **Slovenia**, as Simon Weiss – the current deputy leader of the IOI team explains, includes: 1) School level competition; 2) State level competition; and 3) Playoff competition for IOI/BOI team selection. The School level competition is conducted in schools. The best contestants from this competition are invited to participate in the State competition. For the State competition, contestants are divided into 3 groups: easy group (implementation and basic algorithms), medium group (which requires many different skills from contestants), and advanced group (for the best contestants). All the contestants that achieve a reasonable score from the advanced group, the best few contestants from the medium group, and the best contestant from the easy group, are then invited to participate in a one-day Playoff competition for selection of teams for BOI/IOI. Typically, the number of participants in the School level competition is over 200, 75% of which qualify for the State competition, and 15 contestants make it to the Playoff competition.

As elaborated by Constantin Galatan, the national coordinator for the contests in informatics, in **Romania**, the NOI and IOI related activities are directed and financed by the Ministry of Education of Romania. The National Olympiad in Informatics (abbreviated as ONI in Romanian) has two sections. The first section includes lower-secondary school students: 5th to 8th grade (10–14 years of age). The second section is for high school students: 9th to 12th grade (15–18 years of age). Similarly, the National Training Team consists of two distinct sections: the Junior Training Team, addressed to students from lower-secondary school level (10–14 years of age); and the Senior Training Team, composed of upper-secondary school level students (15–18 years of age).

The Romanian National Olympiad in Informatics is organized in three stages: 1) Municipal Olympiad in Informatics (OMI); 2) County Olympiad in Informatics (OJI); 3) National Olympiad in Informatics (ONI). The National Training Team Selection includes another three stages: 4) Selection contest for the Junior and Senior National Training Teams; 5) First training camp; 6) Second training camp.

For the first three stages, the students from 5th to 10th grade receive different tasks according to the level of study. The tasks for the 11th and 12th grades are the same. Once ONI is finished, the National Training Team is selected in the following manner: first, the Selection Contest for the Junior and Senior National Training Teams is organized and it is a one-day onsite contest. The first 50% of the students in the ONI contest in each level of lower-secondary school take part in this Selection contest. The same happens in the case of high-school students who participate in the Selection contest for the Senior National Training Team. In order to select the National Team, the results from ONI are also taken into consideration.

Regarding the training of the IOI candidates in Romania, two dedicated training camps are organized, 7 days each. Usually, the first training camp takes place at the end of April or early May, and the second one in mid-May. In between, there are online sessions, but they are not part of the official training schedule of students preparing for IOI. They participate in contests organized by Romanian websites such as `infoarena.ro`.

According to Biserka Yovcheva, professor involved in the Bulgarian competitions, the **Bulgarian** national team for the international competitions is selected in several stages. First, the broader national team is selected through the National Olympiad in Informatics (NOI). NOI is organized in three stages:

(1) Municipal competition – organized by local teachers in schools, on town level. Typically, more than 1000 students participate in the competition.
(2) Regional competition – also conducted onsite, on town level, but using tasks prepared by the National Committee of the Ministry of Education and Science. The task solutions are checked by the National Committee and around 120 contestants qualify for the next stage, in 5 groups: E, D, C, B, and A.
(3) National competition – the final competition. Typically, the best 25 contestants from the group C, 20 contestants from the group B, 32 contestants from the group A, and 40 contestants from groups D and E gain the right to participate in this competition.

The junior national team is selected from the participants of the group C, while the senior national team is selected from the participants of the groups A and B. The best 12 junior contestants and the best 12 senior contestants from the National competitions are invited to take part in additional 4–5 competitions before the national teams of 4 students (each) are selected.

Preparations for the selected teams (senior/junior) are conducted twice per year – a 3 day preparation camp in June, in Sofia, and another 7-day camp in July. So far, these preparations have been financed by the “America for Bulgaria” foundation.

There is a project within the Ministry of Education and Science in Bulgaria, named “Student Olympiads and competitions”, for covering the finances for all the activities in the annual competition cycle. However, the project doesn’t always cover the costs completely, so sometimes schools and sponsors provide some of the money. Furthermore, there is a Natural Science Olympic Teams Society, which is funded by the “America for Bulgaria” foundation, and which also participates in the financing.

As described in (Can *et al.*, 2015), the **Turkish** national team for IOI/BOI is selected after the conduction of 3 contests and 2 training camps. First, a paper-based exam on national level is held to select students that will participate in a summer camp. Nearly 1300 students from all over Turkey participate in this first-level exam, which usually is held in May. The top 55 students from the exam qualify for the summer camp. The summer camp lasts for 2 weeks, starting in late August and ending in early September. Lecturers in this camp are typically academics from the most respected universities in Turkey. After the summer camp, another contest is organized, and students that achieve high scores in this contest are invited to participate in a winter camp. The contest is performed in two days, according to the IOI standards, and it takes place in November. The best 18 students in this second contest are allowed to attend the winter camp. The winter camp also lasts for 2 weeks, during February. The final step of the selection process is yet another contest following the winter camp, from which the best 4 students are selected to be part of the national team that represents Turkey at the international competitions – IOI and BOI.

Preparations for the national IOI/BOI team are organized in the 2 weeks preceding the actual IOI. These preparations are usually held in Ankara, and include a contest in each of the preparation days.

A critical stakeholder, which provides the finances and maintains the organizational structure of the Olympiads in Turkey, not just in Informatics, but also in other subjects (such as Mathematics, Physics, Chemistry, and Biology), is the government agency TUBITAK. Each year, TUBITAK forms an official scientific executive committee, consisting of 3 academics from universities, and this committee is responsible for all the scientific matters – from task preparation to selection and training of national teams. The scientific committee, in collaboration with TUBITAK, organizes the paper-based exam in the first level as well as the training camps, and executes all the administrative tasks regarding the participation of the national team in IOI. It also recruits faculty members, interested graduate students, as well as alumni from previous years, to teach the contestants and help them practice for competitions during the training camps.

Competitions in informatics are held in **Macedonia** since 1990, and, by 2018, 29 national contest cycles have been conducted – which include multiple competitions each year, selection contests for international competitions, as well as training camps. Every year the contestants go through many levels of competition so that the best could be selected. The selected pupils represent themselves and Macedonia at the (Junior) Balkan Olympiad in Informatics (BOI/JBOI), European Junior Olympiad in Informatics (EJOI) and the International Olympiad in Informatics (IOI), as well as at other smaller regional competitions. The main organizer of the competitions in informatics for primary and secondary school pupils is the Computer Society of Macedonia (Kostadinov *et al.*, 2015). The total budget for the complete cycle that is raised mainly by sponsors is around 8000 euros per year.

The format of the competitions evolves each year, depending on many factors, such as the number of interested pupils, available resources, inclusion of programming in the schools' curricula, etc. The number of participants in the base contest is approx. 450, including around 50 juniors. Presently, the competitions are organized for primary and secondary school pupils, and include: School Qualification Competition, Regional/Municipality Competition, National Competition, National Olympiad, and (potentially) Selection Contests for International Competitions.

In order to support several competition types, to enable a large number of students to participate in the competitions, and to introduce as many pupils as possible to the art of programming, all of the competitions in informatics that are part of the national contest cycle (accredited by the Ministry of Education), are organized using the MENDO competition management system (Kostadinov *et al.*, 2010).

We have summarized the gathered information above in Table 1. As it can be seen, different countries include different ***number of students in the first (base) contest, which is not strictly proportional to the population*** of the respective countries. The smallest number of students is in Montenegro (only 15 to 20), and the largest number is in Romania (4000). Turkey involves 1300 pupils in the competitions although it is the country with highest population among the examined countries. The ***number of cycles*** through which the teams for international contests are elected also ***varies***

from 2 (Montenegro) ***to 5*** (Romania, Bulgaria, Macedonia). Training of contestants is present in each country, but the form, quantity and regularity differs. ***Finances***, as an important issue, vary from country to country. Firstly, some of the countries have organized state institutional support, while others depend on sponsors and sporadic institutional support. ***The budget varies from 7 000 to 80 000 euros*** (as an approximative value, since the support is given from different state institutions for different activities throughout the annual cycle).

Table 1

Summary of current situations in selected countries from SEE

Country	Levels in the competition cycle	Number of 1st level participants	Training of contestants	Financing
Serbia	Municipal, Regional, National, Serbian Olympiad in Informatics (SIO)	Over 1200 senior and around 750 junior contestants	Online tournaments (via the online judge system Petlja), preparations organized by some schools, training camp for the selected teams (JBOI/EJOI and BOI/IOI)	Before 2016, no financial support whatsoever for training camps, only travel costs for international Olympiads covered by Ministry of Education. Starting from 2016, a budget of 10 000 euros is allocated by the Ministry of Trade, Tourism and Telecommunications of Republic of Serbia
Montenegro	School level competition, State competition	Between 15 and 20	Training camp for the best contestants in the State competition	School competitions are organized and financed by schools; state competitions and training camp organized by the Examination Center of Montenegro, which also covers the travel costs for international Olympiads
Slovenia	School level competition, State competition, Playoff competition for IOI/BOI team selection	120 (plus 100 junior contestants)	Preparations (2 lecture cycles) for the best contestants in the State competition	Budget: 7 000 euros
Romania	Municipal Olympiad in Informatics (OMI), Country Olympiad in Informatics (OJI), National Olympiad in Informatics (ONI), Selection Contest for Junior and Senior National Training Team, First and Second training camp	Around 4000 students	Two training camps (7 days each), online contests organized by Romanian websites such as `infoarena.ro`	All the activities are directed and financed by the Ministry of Education of Romania

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Table 1 – continued from previous page

Country	Levels in the competition cycle	Number of 1st level participants	Training of contestants	Financing
Bulgaria	Municipal, Regional, National Olympiad in Informatics, 4–5 additional competitions for the national (IOI/BOI/JBOI/EJOI) team selection	More than 1000 students	Preparations for the selected teams for IOI/BOI – 2 camps (a 3-days and a 7-days camp)	Budget: 80 000 euros. There is a national project for financing by the Ministry of Education, but sometimes schools, sponsors or even parents participate financially. There are also other sources of financing as well, e.g. the "America for Bulgaria" foundation
Turkey	First National Paper-Based Exam, Programming Contest, Team Selection Contest (IOI/BOI)	Approximately 1300 students	Summer School (2 weeks), Winter School (2 weeks), IOI camp (2 weeks)	Financing provided by the government agency TUBITAK. Budget: 40 000 US dollars
Macedonia	School Qualification Competition, Regional and National Competition, National Olympiad, and (potentially) Selection Contests for International Competitions	Approximately 450 students	Sporadic summer schools (around 1 week)	Financing provided by sponsors of Computer Society of Macedonia. Budget: 8 000 euros

4. A New Approach for Comparison of the Countries' Achievements

Each country is represented at the international Olympiads with a fixed number of candidates, i.e. each country may bring up to 4 contestants at IOI, up to 6 contestants at IMO, and so on. This clearly creates a challenge if someone wants to measure the achievement of one country compared to another. The main inequality is that each country is represented with a fixed number of contestants instead of some kind of proportional or merit-based quotas. A country with population of two million people is obviously expected to achieve a lower result than a country with population of 20 million, or even two billion. The question is – by how much?

As stated in (Taylor, 2012): "The attitudes of the IMO and IOI are almost diametrically opposed when it comes to publication of results. Although earlier I recall the attitude of the IMO to scores was to emphasize that the IMO was an individual rather than team event, IMO now on its official web site `https://www.imo-official.org/results.aspx` publishes the results of every student question by question, even if they get no points, and they also provide official placing for each country each year. This is accepted and completely non-controversial within the IMO community. There are two possible ways of providing a premiership for countries. One would be ***to use every point won by the student*** (as IMO does), while the other, which I have seen done by Australian colleagues from other science Olympiads, is ***to use a medal count based on something like 3, 2 and 1 points for Gold, Silver and Bronze***."

In the last years IOI also started publishing the complete lists of results for each student, so the principle mentioned above may also be applied for these results as well.

Anyhow, these approaches that we see at the Olympiads' websites and the websites related to people from Olympiad communities do not consider the characteristics of each country, especially the country's population.

Our approach proposal is to take into account the population of the countries in question. For example, if you consider country A with population of a and country B with population of b, then one should expect that out of the first n students in the ranking of the students from both countries, approx. $C_a = (a * n) / (a + b)$ should be from country A and approx. $C_b = (b * n) / (a + b)$ from country B, and this should stand for every n, when the countries are equally strong.

For example, if A is a country with population of 2 000 000, and B is a country with population of 7 000 000, then for $n = 2$, $C_a = 0.44$ and $C_b = 1.55$, which means that from the first 2 students either both should be from country B or in rare occasions one from each country. For $n = 4$, $C_a = 0.88$ and $C_b = 3.11$, which means that from the first 4 students either one should be from country A and 3 from country B or in very rare occasions all of them should be from country B. For $n = 6$, $C_a = 1.33$ and $C_b = 4.66$, which means that from the first 6 students either one or rarely 2 should be from country A and 5 or rarely 4 from country B.

From the above example, and if we consider that at IOI every country participates with 4 contestants, for the particular 2 countries (A and B), if the country A has 1 student ranked in the first 4 or 5 students from the joined ranking list, then one may consider that these 2 countries have achieved similar results. Every situation in which a student from country A is ranked higher than fourth place in the joined ranking gives "advantage" to the country A.

We believe that this approach is much more fair and precise, when used to compare 2 countries. Although it cannot be efficiently used when the population of the countries is dramatically different (i.e. the ratio B/A or A/B is greater than 5) for a specific year, it becomes usable when comparing the countries over the period of more than one (consecutive) years, by putting the contestants from all years in a joined ranking list.

This comparison approach that we propose may be used for analysis of the achievements of a country. The result may confirm (or throw away) the methods and approaches used in that country in their education and competition cycles organization.

In the following section we will give a short case study with focus on the results achieved by Macedonian contestants, compared to some of the neighboring countries.

5. A Case Study of the New Approach for the Macedonian Achievements

Organizer of the informatics competitions in Macedonia is the Computer Society of Macedonia (CSM). The organization of state events deals with large number of participants, which are mostly minors (under 18 years old) and, also, with the necessary technology on site that requires staff to deal with technology malfunctions. CSM is a nongovernmental, non-profit organization and bases the organization of the competitions solely on sponsorships from companies, educational institutions, and sporadically from donations based on application in some calls for projects. With low finances in mind, CSM employs as cost-effective as possible ways for engaging pupils in the competitions, motivating teachers and school authorities, as well as keeping the participants informed, and "in good condition". Among the challenges that CSM faced in the beginning of the last decade was the small number of children involved in the competitions, which, of course, led to results that were not noticeable in the worldwide IOI ranking (Jovanov *et al*., 2017).

The challenges mentioned above inspired continuous evolution of the format of the competitions. The changes undertaken ever since depend on many factors, such as the number of interested pupils, the inclusion of programming in the schools' curricula, etc. Also, in the year 2010 the competition system called MENDO was developed and introduced in the management and execution of the competitions (Kostadinov *et al*., 2010). All the improvements throughout the years, led to enhancement of the interest of pupils, and more and more pupils joined the competition process. From 48 pupils involved in the first round of competitions in year 2009, the interest rose to approx. 450 pupils in 2017. All of the aforementioned improvements, in turn, resulted in higher quality in the pupils' achievements. The achievements of the pupils in the Olympiads in Informatics are presented in Fig. 1. In this figure, the medals won by Macedonian competitors at the international competitions in informatics (IOI, BOI, and JBOI), in the period 1996–2016 are shown. There is a very obvious increase in the number of medals won, prior and following 2010. The last period is the one that involves the

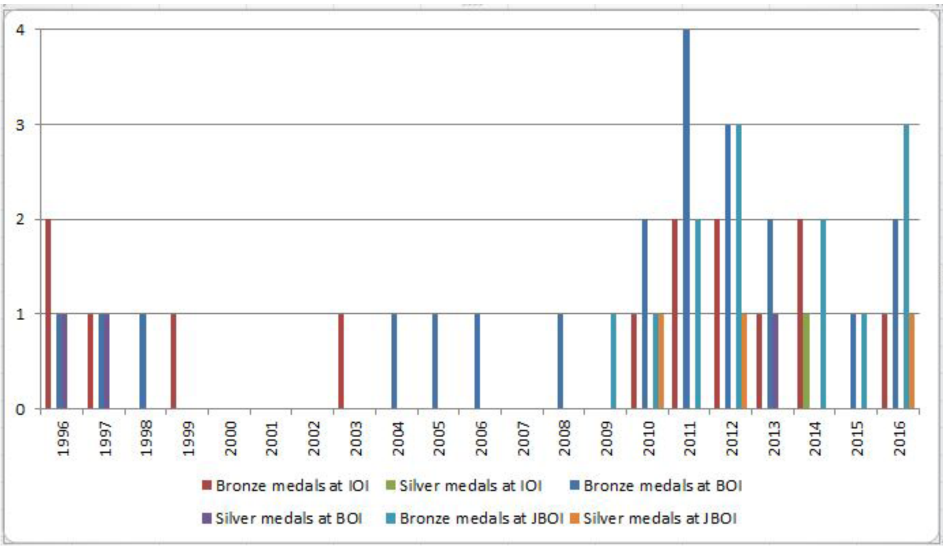

Fig. 1. Medals won by Macedonian competitors at the international competitions in informatics (IOI, BOI, and JBOI), in the period 1996–2016 (Jovanov *et al*., 2017) .

great changes in the competitions (the form and the tools for organization) and in the educational curriculum (Jovanov *et al*., 2017).

Anyhow, as organizers of the competitions, we always ask ourselves the following questions: Have we managed to reach the maximum result for Macedonia? Is Macedonia's performance on the same level as the neighboring countries, even without the regular support from the government and the state budget?

The population of Macedonia is around 2 000 000 (CIA, 2018). The highest achieving neighboring countries of Macedonia (countries from SEE region) are Serbia (population around 7 000 000 (SORS, 2018)), Bulgaria (population around 7 000 000 (NSI, 2017)), and Romania (population around 20 000 000 (INS, 2012)). If we employ the new approach, it would mean that in the competition including the best participants from Macedonia and Bulgaria or Serbia, there should be one Macedonian in the first 4 students (based on the calculations from the previous section), or in a match between Macedonia and Romania, in the first 11 students there should be one Macedonian. Since IOI is usually attended by the four best contestants from each country, whenever one contestant of Macedonia is placed in front of a student from Bulgaria and Serbia, this is a success equal to the success of those two countries. In the last two IOIs the best Macedonian competitor has always been ranked in front of at least one competitor from Bulgaria, Serbia and Romania. Therefore, we may consider the Macedonian results at IOI at least equal to the strongest countries in our region.

We would not go into further deliberations and comparisons, because the focus of this paper is on the applicability of the new approach, and not on the particular achievements of Macedonia. ***Presented case clearly shows its applicability***.

6. Conclusion

In this paper, at the beginning, we have identified and summarized the necessary topics important for achieving good results at international scientific Olympiads. Further, we have presented thorough analysis of the contest systems of selected countries from South Eastern Europe (SEE) in the field of Informatics (Computer Science), as a region that is one of the prominent world regions in the context of high results in the international competitions. The characteristics of the informatics contest systems of Romania, Bulgaria, Serbia, Montenegro, Slovenia, Macedonia and Turkey were then summarized in a table, for easy comparison.

Further we presented a new approach that may be used to compare the achievements of countries based on the results that students achieved at Olympiads, and then we gave an application of this approach on the results of some of the discussed countries, compared to Macedonia.

We strongly believe that the content presented here, and the given approach for comparison, will be a valuable tool for the entities involved in the organization of the contests, to measure their results compared to other countries, to use the information for improvement, and to use their achievements to raise awareness among the government institutions and companies in order to get support from them.

Acknowledgement

The research presented in this paper is partly supported by the Faculty of Computer Science and Engineering, at the Ss. Cyril and Methodius University in Skopje. Authors wish to thank Jelena Hadzi-Puric, Ranko Cabrilo, Simon Weiss, Constantin Galatan, Biserka Yovcheva and Fatih Demirci, for supplying the information regarding the current situation with the national competition cycle in their respective countries.

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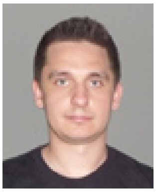

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