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Israel: The Regional and National Competitions

Ela ZUR[1], Tamar BENAYA[1], Oren BECKER[2], David GINAT[3]

[1]*The Openu University of Israel, Computer Science Department*
108 Ravutzky st., 43107 Raanana, Israel
[2]*The Hebrew University, Mathematics Department*
Jerusalem, Israel
[3]*Tel-Aviv University, Science Education Department*
Ramat Aviv, 699978 Tel-Aviv, Israel
e-mail: {ela, tamar}@openu.ac.il, oren.becker@gmail.com, ginat@post.tau.ac.il

Abstract. This year the Israeli Ministry of Education has decided to increase its support and involvement in the IOI project. The main goals of the increased involvement were to expose the project to a wider audience, and to expand the team selection and training process. For the first time, a regional competition was conducted before the national competition. In this paper we describe the aims, scope, and contents of the regional and national competitions, and provide some statistics about the students' backgrounds and views about these competitions.

Key words: regional competition, national competition.

1. Introduction

The IOI – the International Olympiad in Informatics – is the primary computer science (CS) competition for young (secondary school) students. The primary goal of the IOI is to stimulate challenge in CS among exceptionally talented young students from all over the world, and have them share scientific and cultural experiences. Each participating country conducts a preparation process, and brings to the IOI a team of (at most) four contestants. During the IOI, the contestants compete individually in solving and programming challenging algorithmic tasks. Different countries invest different amounts of effort and resources in preparing their IOI teams (e.g., Diks *et al.*, 2007; Casadei *et al.*, 2007; Philips, 2010; Tsvetkova, 2010; Wang *et al.*, 2010).

In Israel, until 2010, the IOI project was composed of four stages: a self-study towards the national competition; a national competition, an advanced training and team-selection stage, and the national team's preparation for the IOI. A detailed description appears in the Israell IOI website and in our previous paper (Zur *et al.*, 2010). This year, an increased support by the Ministry of Education enabled us to conduct a preliminary stage of a regional competition. This competition was aimed for a large audience, including students with very limited programming experience. The better students in this competition were invited to the national competition. In what follows, we describe our experience with the new regional competition and its successive national competition, and provide some statistics regarding the students' backgrounds, motivation, achievements and points of view.

2. The Regional and National Competitions

The regional competition was the first stage of this year's olympiad project in Israel. Our goal was three-fold: 1. to offer algorithmic challenge to an audience as wide as possible; 2. to engage CS secondary school teachers in posing the challenge; and 3. to identify competent students, who will advance in the project activities.

We developed a 5-question questionnaire, which was posted in the website of the CS inspector of the Ministry of Education. The questionnaire was posted at a given time in mid December, which was a-priori told to all the secondary schools in Israel. Secondary school teachers, in 110 schools, downloaded the questionnaire, and posed it to their selected students, as a 2-hour exam. Questions during the exam, about the exam tasks, where directed in real-time (phone) by the teachers to our team. All in all, 1442 students participated in the exam. The students wrote their answers on exam sheets, which were downloaded from the internet. All the sheets were sent to our team for grading. A couple of days after the exam, we posted the solution, with broader perspectives of notions that appeared in the exam questions.

The teachers' role in this activity was to encourage their better students, and have them take the exam. They supervised their students during the exam, and sent us the student notebooks. Our hope was that teachers will be enthusiastic about posing challenge to their competent students, be motivated themselves to solve the questionnaire questions, and become interested in the olympiad contents. This expectation was met only to a limited extent.

The amount of secondary schools that participated in the exam was about 20% of the secondary schools in Israel – much more than in previous years, but still limited. Most of the teachers who engaged their students in the activity cooperated well with us, and enjoyed the exam questions, but only some showed further interest in the olympiad contents. Many felt that the olympiad contents are too challenging for them, and their role is mostly to link their competent students to the project. In addition, some teachers did not expose their students to the project, as they felt incompetent with challenging questions, and did not want to reach an "embarrassing" situation in front of their students, in which they could not solve the exam questions themselves. We hope to change this attitude in future years.

As one of our goals was to expose the project to an audience as wide as possible, we posed algorithmic tasks for which the required answers were not an algorithm, but rather the outcome of an algorithmic computation. This is in line with the approach presented by Burton (2010) and Kubica and Radoszewski (2010). This approach offers the opportunity of reaching students who are less acquainted, or even unacquainted with programming. The exam questions focused on mathematical and algorithmic insight, on which one had to capitalize her/his computation. For example:

Question 2 of the Regional Exam.

Given the following set of integers {4, 97, 357, 29, 22, 7, 14, 377, 1, 80, 331, 2, 320, 401, 258}, calculate the following, and explain your calculation in a few sentences.
1. What is the lowest integer that cannot be generated by adding integers of that set? (For example, if the set was {1,2,6}, the answer would have been 4.)

Hint: the answer is an integer whose units-digit is one of the integers in the given set.

2. Is there an integer in the set, whose replacement with its doubled value (e.g., replacing 4 by 8) will yield a larger result in Section 1?

Section 1 of the above question appears in some mathematical-challenges texts, as well as in Kubica and Radoszewski (2010). The challenge is to identify two patterns: **1.** the relevance of ordering the given integers; and **2.** if we can generate all the integers up to the value S, with the first k integers in the ordered sequence; and the $k+1$ integer is v, who is not larger than $S+1$; then we can generate all the integers up to $S+v$; if, on the other hand, v is larger than $S+1$, then $S+1$ is the answer (output).

The question does not require the explicit phrasing of an algorithm, but rather an algorithmic computation with the given data. Thus, one may answer the question even when less acquainted with programming. Yet, there are two drawbacks:

– one may make a calculation mistake, and yield an erroneous integer as output;
– one may solve Section 1 without really obtaining full insight.

In order to address the first drawback, we offered a hint, with which one could check her/his calculation result. In addition, we asked for a short description of the result in free text. In examining the ”hint statistics”, we noticed that out of the 1442 students who took the exam, only 13 (less than 1%) yielded an erroneous calculation upon having the right insight (wrong output, correct text description). About 25 students ($\sim 2\%$) indicated that they guessed the output for Section 1, from the hint; but the vast majority of their guesses were erroneous.

Addressing the second drawback was more subtle. We felt that we had to ask for some further insight, as one could answer Section 1 by ordering the integers, and then advancing in a greedy manner, without sufficiently understanding the task characteristics. Thus, we added Section 2. And indeed, of the 1442 students, 433 answered Section 1 properly, but only 203 answered Section 2 properly. That is, less than 50% of those who answered the question, demonstrated sufficient insight.

The rest of the exam questions were characterized as follows. Question 1 required capitalization on a simple string pattern; Question 3 was similar to Question 2; Question 4 involved some basic recursive view, which was simple to calculate by applying dynamic programming; and Question 5 involved the specification of rules for a hat-colours challenge.

All in all, the total score that one could obtain was 125. We invited to the next stage all those who obtained a score of 80+, plus students who obtained a lower score but nicely answered one or more of the insightful sections in the questions. We expected students to learn from our posted solution, and from our previous national competitions, in preparing to the next stage – the national competition.

The national competition was held in the beginning of February, and was attended by 668 students. We posed four algorithmic tasks, to be answered by paper and pencil. Task 1 involved avoiding a misleading greedy computation and applying simple dynamic programming; Task 2 involved a mathematical game, for which one had to recognize an invariant; Task 3 involved optimization of counting the number of operator's operations; and Task 4 involved enumeration that was tied to inductive insight. Task 3 is displayed below.

> **Task 3 of the National Exam.**
> Given a 2×N matrix, randomly coloured black and white, and an operator that switches the colours of the cells in a given (as a parameter) rectangle of cells; output the minimal number of the operator's invocations in order to turn the matrix colours into a chessboard colouring.
>
> E.g., for the input:
>
> | | | |
> |---|---|---|
> | W | W | B |
> | B | B | B |
>
> The output will be 2. (One way of operating the operator is by first applying it on the two right columns, and then – on the bottom-right cell.)

We devised the above task by simplifying (considerably) the XOR task of IOI 2002. Our intention was to examine whether students recognize two relevant patterns – the rather simpler pattern that the operator's relevant impact is primarily on the vertical sides of its rectangles; and the pattern that sole processing of single-row rectangles may not be sufficient for optimality, and one may have to "touch" both single-row rectangles and double-row rectangles.

3. Student Backgrounds and Views

We conducted a preliminary study among the students who attended the national competition, in an attempt to learn about their backgrounds, motivation, and viewpoints regarding the regional and national competitions. We briefly describe the study's methodology and then display and discuss the results.

We posed an 18-questions questionnaire that focused on the students' CS education, their demographic environment, their preparation for the competitions, and their opinions about the questions in both competition exams. The questionnaire was answered by 513 of the students who attended the national competition.

We found that 28% of the students have at least one parent who is involved in a CS-related career such as high-tech industry or CS education. 85% of the students were male students, in spite of our efforts throughout the years to increase female participation. The students of the national competition came from 93 different secondary schools in the country. Their age distribution is displayed in Table 1.

As we can see, over 75% of the students are in their last two secondary school years. This finding is correlated with CS education in Israel, which usually starts at 10th or 11th grade. The drawback in this finding is that we first meet the vast majority of the competent students in a rather late age, thus most of them may learn from us and develop for a very limited time.

Table 1

Students' age distribution in the national competition

8th grade (age 14)	9th grade (age 15)	10th grade (age 16)	11th grade (age 17)	12th grade (age 18–19)
0.6%	1.8%	21%	44.5%	32.1%

In Israeli secondary schools, every student has to study several required subjects and at least one optional subject in depth. Mathematics is one of the required subjects and it must be taken throughout the secondary school studies. A student may select the level of studies which suits her/his interests and ability. The mathematics curriculum may be studied in one of three levels: 3 points, 4 points, and 5 points. Each point represents 90 class hours. We found that 87% of the students who participated in the national competition have selected the highest level of 5 points, while the rest selected the second level (4 points).

Starting from the 10th or 11th grade, CS is one of the optional subjects that a student may select to study in depth. The CS curriculum includes several courses starting with a Foundations course followed by a Software Design course. A detailed description of the Israeli secondary school curriculum is described in Gal-Ezer *et al.* (1995) and Armoni *et al.* (2010). We found that 95% of the students selected CS as their optional subject. 12% of them have not yet started their CS studies, 88% are currently studying or have completed the Foundations course, and 61% are currently studying or have completed the Software Design course.

We also found that 85% of the students selected an additional scientific subject such as: Physics, Chemistry, Biology, or the like. The most popular additional subject is Physics which was selected by 75% of the students.

The students were asked about their plans for university studies and career direction: 53% of them said that they would like to study CS in the university, or plan to have a CS career. 43% of them said that they didn't decide yet.

Over 90% of the students indicated that they came to compete after being encouraged to do so by their teachers. We allowed participation in the national competition for those interested, even if they did not participate in the regional competition. 35% of the participants were such participants. When asked for the reason for not participating in the regional competition, most of these 35% claimed that the regional competition was (unfortunately) not offered in their schools.

When asked whether they studied for the competitions, 21% of the students replied that they prepared to the regional competition and 37% prepared to the national competition. In both cases, the students learnt from the examples in the Israeli IOI Website, and a few were helped by their teachers.

The students expressed different opinions about the levels of difficulty of the regional and national competitions. Their opinions are displayed in the Table 2.

Table 2
Students' viewpoints of the competitions' levels of difficulty

	Regional competition	National competition
Difficult	21%	74%
Partially difficult	56%	23%
Easy	23%	3%
Interesting	92%	90%
First encounter with such questions	59%	71%

Some student added comments to their evaluation, such as: "I lack the knowledge required for answering such a question", "I did not understand the question", "The question requires a lot of thinking" and "I have never encountered such a question".

We may notice that the vast majority of the students in both competitions found the questions interesting. Some additional comments were: "The questions were very interesting and challenging", "The questions were fun and stimulated creativity", "I like riddles and logic questions".

We took a further look, and examined the top 50 students which were selected to participate in the advanced training stage. Only 27 of them (54%) participated in the regional competition. The average grade of these 27 students in the regional competition was 101 (out of 125).

We examined the background of the top 50 students and compared it with the background of the national competition participants; the results are displayed in the Table 3.

We may notice that the top students are strong in mathematics, and have a strong inclination to Physics. The amount of females in the top group is too low, and we should seek ways to encourage the participation of the most competent girls. Finally, we are glad that the vast majority of the top students are not from 12th grade, yet we should seek ways to increase the amount of younger students in the top group.

Table 3
Comparison of students' background

	Top 50 students	Participants in the national competition
Selected the highest level of mathematical studies (5 points)	100%	87%
Chose to expand their CS studies in secondary school	95%	95%
Chose to expand their hysics studies in secondary school	92%	75%
Females	2%	15%
Students in the 10th or 11th grade	79%	75%

4. Conclusion

We displayed some contents and statistics of our regional and national competitions. For regional competitions, it may be beneficial to carefully examine, how exactly do tasks without programming reflect competence in algorithmic thinking. As for our statistics, one conclusion that evolves from the data is that we should develop additional ways to increase teachers' motivation and involvement in the IOI project. We should increase our efforts to attract more girls. In addition, we should familiarize students with CS challenges, of basic levels, prior to both competitions; and we should find ways to reach younger talented students prior to the time in which they start studying CS in secondary school. This will enable us teaching these students for a longer period of time, and better preparing them for the IOI.

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E. Zur – is involved in the Israel IOI project since 1997, and repeatedly served as a deputy leader. She holds a PhD Degree in computer science education from Tel-Aviv University. She is a faculty member of the Computer Science Department at the Open University of Israel. She designed and developed several advanced undergraduate computer science courses and workshops, and currently serves as a course coordinator of several courses. Her research interests include distance education, collaborative learning, computer science education, computer science pedagogy, teacher preparation and certification and object oriented programming.

T. Benaya – holds a MSc in computer science from Tel-Aviv University. She is a faculty member of the Computer Science Department at The Open University of Israel. She designed and developed several advanced undergraduate computer science courses and workshops, and she serves as a course coordinator of several courses. She also supervises student projects. She is a lecturer of computer science courses at The Open University of Israel and Tel-Aviv University. Her research interests include distance education, collaborative learning, computer science education, computer science pedagogy and object oriented programming.

D. Ginat – heads the Israel IOI project since 1997. He is the head of the Computer Science Group in the Science Education Department at Tel-Aviv University. His PhD is in the computer science domains of distributed algorithms and amortized analysis. His current research is in computer science and mathematics education, focusing on cognitive aspects of algorithmic thinking.

O. Becker – is a former IOI contestant and has been involved as a staff member in the Israeli IOI project since 2005. He was Israel's team leader to IOI 2009, IOI 2010, and is currently Israel's team leader to IOI 2011. He is currently in his last year of BSc studies of mathematics in the Hebrew University of Jerusalem.