Competitions and Olympiads
Олимпиади и състезания

ANALYSIS OF PROBLEM SOLVING IN INFORMATICS FOR 12 – 13 YEAR OLD STUDENTS IN BULGARIA

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Abstract. The present study aims at characterizing the solutions of tasks in Informatics from National competitions and Olympiads for Group D students relevant to 6th school grade. The study covers a 10-year-period (2004-2013). An application proposes a classification of these tasks based on their main characteristics. An evaluation of the relative difficulty of the tasks is also included.

Keywords: Olympiad, Informatics, task, classification

Over the recent years competitions in Informatics have rapidly increased, both in our country and abroad. Bulgaria could be proud with very good results achieved in Informatics competitions, both national and international. Since 2001, regularly each year Bulgaria organizes six national competitions in Informatics following exactly the same rules and regulations as those of the International Olympiad in Informatics: 3 tournaments per year (in autumn, winter and spring) and 3 rounds of the National Olympiad. Since 2002, the competitions in Informatics have been targeting participants of different age groups: group A (11 – 12th school grade), Group B (9 – 10th school grade), group C (7 – 8th school grade) and group D (4 – 6th school grade).

In the autumn of 2004 the group E has been introduced which includes 4 – 5th school grade and this has led to a new distribution of the age groups: A, B, C and D, covering 12th, 10-11th, 8-9th and 6-7th school grades, respectively. In the autumn of 2007, with the establishment of the Balkan Olympiad in Informatics (JBOI) for students up to 15.5 years age we have applied a modified age system in which Group D has covered only 6th school grade and the distribution of the other groups are as follows: group A (11 – 12 grade), group B (9 – 10 grade), group C (7 – 8 grade), Group D (6th grade) and group E (4 – 5 grade).

The most important goal of the competitions is to enhance students' knowledge, skills and abilities. Competitions encourage self-education. They are a powerful regulator, because students get the opportunity to assess their own level of expertise. Thus, the participants have the possibility to make necessary adjustments in their further training

and self-preparation. To solve tasks of different competitions successfully, one needs in-depth knowledge not only in the field of algorithms and programming, but also in the domain of Mathematics.

Preparation of students for national competitions involves various extracurricular activities. The main objectives of the extracurricular training in Informatics are:

- ✓ Expanding opportunities for students to demonstrate their practical skills and preparing them to participate in national and international competitions in Informatics.
- ✓ Developing students' algorithmic methods of thinking. Expanding their knowledge in programming. Analyzing and understanding the solutions of different tasks included in Informatics Olympiads.
- ✓ Learning standard algorithmic methods and acquiring skills to apply them to other types of tasks.
- ✓ Developing creative thinking, teaching a creative approach to task solving. Thought - provoking methods aiming at improving the effectiveness of the algorithms and their rapid functioning.
- ✓ Enjoying moral and emotional satisfaction with their achievements.
- ✓ Developing self-discipline, perseverance, sportsmanship and striving for self-education (Старибратов & Танева, 2009).

In this paper we follow Emil Kelevedjiev's and Zornitca Djenkova's fundamental ideas (Келевджиев & Дженкова, 2008) and (Келевджиев & Дженкова, 2012) for problem systematization and classification. After accumulating a sufficient number of tasks from national competitions, it is possible to conduct different kinds of research, for example classifications based on task basic characteristics.

Consider the coefficient $k = (y - x)/(x + y)$, where x denotes the number of the contestants with more than 60 points (out of 100) for task performance and y denotes the number of the contestants with less than 30. The maximum value is $k = 1$ (for $x = 0$), meaning that there is no contestant with more than 60 points, which shows that the task is difficult. The minimum value is $k = -1$ (at $y = 0$), i.e. no contestants' result is under 30 points, which indicates in turn that the task is easy. The coefficient k gives information about the extent to which the authors of the tasks have made the paper selection according to the particular competition and the age of the students. (Келевджиев & Дженкова, 2008)

Below the main characteristics of the tasks are summarized in the following three points:

1. Elements of the programming language related to the types of the processed data in the program: numbers, symbols, strings, one-dimensional and two-dimensional ar-

rays, arrays of strings. The following diagram (Fig. 1) shows the proportion (in percentages) of the processed data in the tasks of group D (2004-2012):

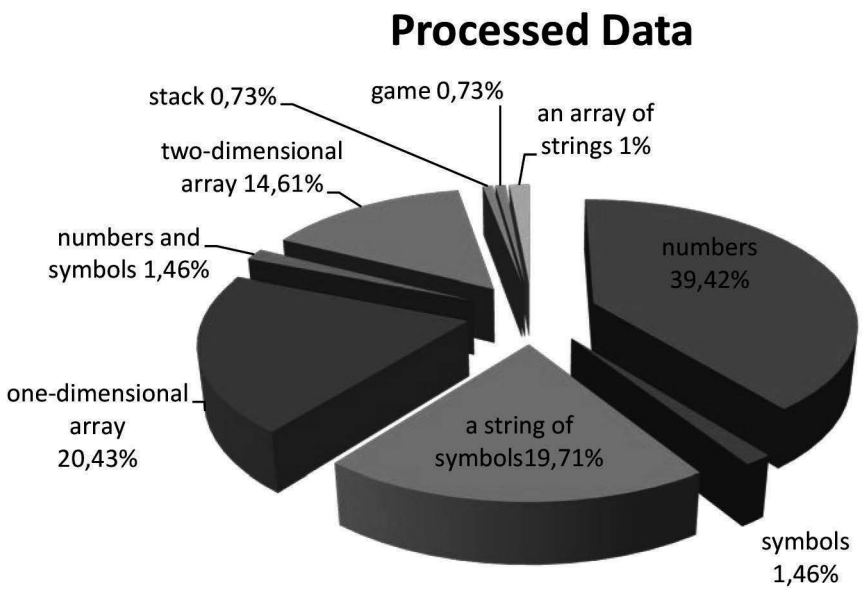

Fig. 1. Processed data for task solving

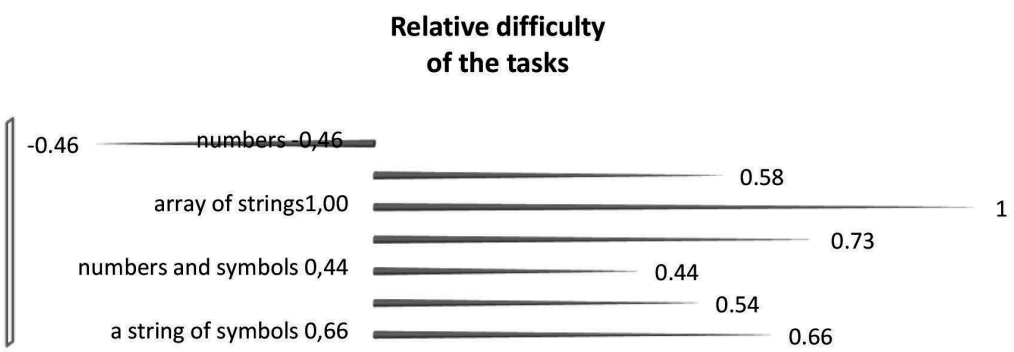

Fig. 2. Relative difficulty of the tasks

It is obvious from the above chart that most of the tasks involving numbers are relatively less difficult. This is completely natural because students use to know this type of data when they are still in Group E (4-5th grade). The tasks with an array of strings as processed data are the smallest in number and pose most difficulties to students.

2. Programming language elements related to the syntactic structures used in the program: conditional operator – if, loop (for, while, do... while), nested loops, use of functions. The following diagram (Fig. 3) shows the proportion (in percentages) of the syntactic constructions in the tasks of Group D (2004-2012):

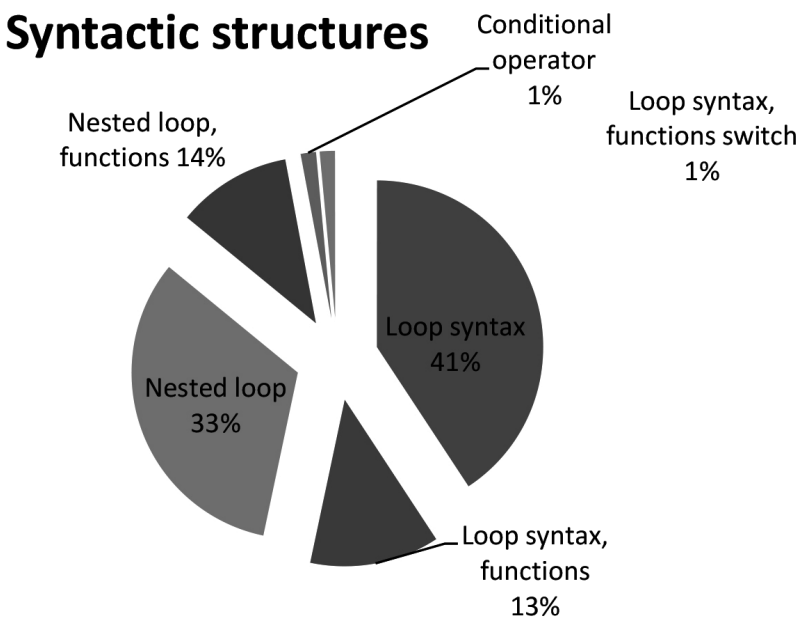

Fig.3. Syntactic structures in task decisions

The relative difficulty of the tasks is established according to the syntactic structures used in the solutions of the tasks of Group D, presented in Figure 4. It is shown in the diagram that students meet relatively more difficulties in doing tasks on loop syntax with functions and nested loops with functions.

3. A theory of data structures and algorithms used in the solutions of the tasks: divisibility, long numbers, classification, number systems, recursion, text processing, geometry – rectangles with sides parallel to the coordinate axes, etc.

Classification of the tasks given in National competitions in Informatics Group D (2004 – 2012)

Legend: NAT – National Autumn Tournament in Informatics; WCI – Winter Competition in Informatics; NOI2 – National Olympiad in Informatics (regional round); NSTI – National Spring Tournament in Informatics; NOI3 – National Olympiad in Informatics; DIGIT – separation and Processing digits of numbers; RSPCA – rectangle with sides parallel to the coordinate axes; OPT – find the optimal (maximal/minimal) element; UNIT – conversion of measure units; SUM – finding the sum of a final number of numbers.

№	Year, competition	Name of the task	Data, Subject	Syntactic structure	Feature/ algorithm	*x*	*y*	*k*
1	2004, NAT	Painter	Symbols	Nested loop	Sign and figure printing	7	16	0,39
2	2004, NAT	Safe	Numbers	Loop syntax	DIGIT	7	17	0,42
3	2004, WC	Word	String	Nested loop, functions	Text processing	0	17	1,00
4	2004, WC	Nice sequence	Numbers	Loop syntax, functions	Recursion	3	12	0,60
5	2004, WC	Multiplication	Numbers	Loop syntax	Divisibility	5	10	0,33
6	2004, NOI2	Game	Numbers	Loop syntax	Divisibility	18	12	-0,20
7	2004, NOI2	Tops	Two-dimensional array	Nested loop		12	19	0,23
8	2004, NOI2	Football systems	Numbers	Loop syntax		8	19	0,41
9	2004, ST	Fractions	Numbers	Loop syntax	Divisibility	4	12	0,50
10	2004, ST	Triangles	Symbols	Nested loop	Sign and figure printing	2	15	0,76
11	2004, ST	Artur	dimensional array	Loop syntax	DIGIT	2	19	0,81
12	2005, NAT	Word in the text	String	Loop syntax	Text processing	4	24	0,71
13	2005, NAT	Calendar	numbers	Nested loop	dates/ printing figures of signs	1	27	0,93
14	2005, NAT	The Millionaire	numbers	Loop syntax	Dynamic Optimizing	0	29	1,00
15	2005, WC	Game	String	Loop syntax		1	24	0,92
16	2005, WC	Crossword	two-dimensional array	Nested loop functions		2	25	0,85
17	2005, WC	Traveling	Stack	Loop syntax		0	26	1,00
18	2005, NOI2	Sites	Two-dimensional array	Nested loop		5	37	0,76
19	2005, NOI2	Rectangle	dimensional array	Loop syntax	RSPCA	12	27	0,38

20	2005, NOI2	Pools	dimensional array	Loop syntax		13	25	0,32
21	2005,NOI3	Arithmetic	numbers Symbols	Loop syntax		2	5	0,43
22	2005,NOI3	Intervals	String	Loop syntax		2	3	0,20
23	2005,NOI3	Crossword	Array of strings	Nested loop		0	7	1,00
24	2005, ST	Game	game	Strategy	Divisibility	3	9	0,50
25	2005, ST	Calendar	numbers	Loop syntax	Dates	4	8	0,33
26	2005, ST	Monopoly	numbers	Loop syntax		4	7	0,27
27	2006, NAT	Library	numbers	Loop syntax		14	12	-0,08
28	2006, NAT	Trains	numbers	Nested loop	Printing figures of signs	18	14	-0,13
29	2006, NAT	Will	String	Loop syntax	Text processing Long numbers	5	25	0,67
30	2006, WC	Yoda	String	Loop syntax	Text processing	11	16	0,19
31	2006, WC	Walleye	numbers	Loop syntax	Divisibility	7	18	0,44
32	2006, WC	MAX3	dimensional array	Loop syntax		2	22	0,83
33	2006, NOI2	Diary	numbers	Loop syntax		28	22	-0,12
34	2006, NOI2	Roads	numbers	Loop syntax		7	46	0,74
35	2006, NOI2	Adjacent cells	Two-dimensional array	Nested loop		24	28	0,08
36	2006, NOI3	Zig-zag	Two-dimensional array	Nested loop		7	9	0,13
37	2006, NOI3	Summer School	dimensional array	Loop syntax	Merging a classified array	5	15	0,50
38	2006, NOI3	Amount	dimensional array	Loop syntax	Generating and modelling	0	23	1,00
39	2006, ST	Zero's	Numbers	Loop syntax	Exponents	1	22	0,91
40	2006, ST	Engendered queues	dimensional array	Loop syntax		3	24	0,78
41	2006, ST	Sticks	numbers	Loop syntax	Recursion	9	17	0,31
42	2007, NAT	Happy years	numbers	Loop syntax		4	23	0,70
43	2007, NAT	Pun	Array of strings	Nested loop		0	26	1,00
44	2007, NAT	Divisibility	numbers	Conditional operator	Divisibility	5	4	-0,11
45	2007, WCI	Bank accounts	String	Loop syntax	DIGIT	13	17	0,13
46	2007, WCI	Including ….	dimensional array	Loop syntax	Classification	5	14	0,47

47	2007, WCI	Seagull	Numbers & symbols	Loop syntax		8	21	0,45
48	2007, NOI2	Rows	dimensional array	Loop syntax		19	6	-0,52
49	2007, NOI2	Task Force	numbers	Loop syntax, function functions		17	6	-0,48
50	2007, NOI2	Article	String	Loop syntax	Text processing	14	6	-0,40
51	2007, ST	Mushrooms	Two-dimensional array	Nested loop		3	12	0,60
52	2007, ST	Melody	dimensional array	Loop syntax		0	16	1,00
53	2007, ST	Table	Two-dimensional array	Nested loop		2	14	0,75
54	2008, NAT	Figures	numbers	Nested loop	DIGIT	15	5	-0,50
55	2008, NAT	Pavedroads	numbers dimensional array	Loop syntax, functions		7	13	0,30
56	2008, NAT	Chocolate	String	Loop syntax, functions		12	6	-0,33
57	2008, WC	Books	dimensional array	Nested loop	Classification	1	19	0,90
58	2008, WC	Mobius	numbers	Nested loop functions		3	14	0,65
59	2008, WC	Excessive numbers	numbers	Loop syntax		5	9	0,29
60	2008, NOI2	Circle	dimensional array	Nested loop		2	29	0,87
61	2008, NOI2	Pets	string	Nested loop	Counting	21	11	-0,31
62	2008, NOI2	Numbers	Two-dimensional array	Nested loop		5	14	0,47
63	2008, NOI3	Expression	string	Loop syntax	Text processing	10	2	-0,67
64	2008, NOI3	Treasure	string	Loop syntax, functions	Text processing	5	15	0,50
65	2008, NOI3	Figures	numbers	Loop syntax		11	4	-0,47
66	2008, ST	Lamps	numbers	Loop syntax		11	6	-0,29
67	2008, ST	Rectangles	numbers	Nested loop	RSPCA	7	16	0,39
68	2008, ST	Meteorologists	string	Loop syntax	Text processing	20	4	-0,67
69	2009, NAT	Rectangles	numbers	Loop syntax		18	6	-0,50
70	2009, NAT	Maximum binary number	string	Loop syntax	Number systems	22	8	-0,47

71	2009, NAT	Garden	numbers	Loop syntax, functions	GCD(the greatest common divisor)	10	7	-0,18
72	2009, WCI	Friends	numbers	Loop syntax		14	5	-0,47
73	2009, WCI	Figures	dimensional array	Nested loop	Long numbers	5	12	0,41
74	2009, WCI	Fatty	numbers	Loop syntax, functions		9	10	0,05
75	2009, NOI2	Pebbles	numbers	Loop syntax	OPT[8]	10	7	-0,18
76	2009, NOI2	Bread and cheese	dimensional array	Nested loop	OPT	11	11	0,00
77	2009, NOI2	Difference	string	Nested loop		5	15	0,50
78	2009, NOI3	Units	numbers	Loop syntax		2	15	0,76
79	2009, NOI3	clock	numbers	Conditional operator	UNIT[9]	3	7	0,40
80	2009, NOI3	At least the product	numbers	Nested loop	OPT	10	6	-0,25
81	2009, NOI3	Soil	dimensional array	Nested loop	SWAP, classification	2	11	0,69
82	2009, NOI3	Farm Pigs	dimensional array	Loop syntax	Classification	1	16	0,88
83	2009, NOI3	Bouquets	numbers	Nested loop		1	2	0,33
84	2009, ST	Difference	numbers	Nested loop	Number systems	2	7	0,56
85	2009, ST	Line	dimensional array	Loop syntax, functions , switch		1	4	0,60
86	2009, ST	Distance	dimensional array	Loop syntax		12	4	-0,50
87	2010, NAT	Number series	numbers	Loop syntax		21	11	-0,31
88	2010, NAT	Parking	String	Nested loop		5	27	0,69
89	2010, NAT	Airplanes	numbers	Nested loop		1	31	0,94
90	2010, WCI	Warehouse	Two-dimensional array	Nested loop	Counting	8	11	0,16
91	2010, WCI	Treasure hunters	numbers	Loop syntax	Divisibility	7	1	-0,75
92	2010, WCI	Balls	numbers	Loop syntax		10	11	0,05
93	2010, NOI2	Fibonacci	numbers	Loop syntax, functions	Calculating by a formula	6	16	0,45
94	2010, NOI2	Magic lines	numbers	Nested loop		19	3	-0,73
95	2010, NOI2	Tetris	Two-dimensional array	Nested loop	Counting	8	10	0,11
96	2010, NOI3	Lining	Two-dimensional array	Nested loop		8	8	0,00

97	2010, NOI3	Water	dimensional array	Loop syntax, functions	Classification	4	15	0,58
98	2010, NOI3	Poker	Two-dimensional array	Nested loop functions	OPT	12	6	-0,33
99	2010, NOI3	Flag	String	Loop syntax, functions	Text processing, SWAP	11	6	-0,29
100	2010, NOI3	The last digit	dimensional array	Nested loop	Divisibility	2	16	0,78
101	2010, NOI3	the Time Machine	String	Nested loop	Text processing, classification	3	9	0,50
102	2010, ST	Runners	dimensional array	Nested loop functions	Logical	2	13	0,73
103	2010, ST	True equality	dimensional array	Nested loop functions	Number systems	0	14	1,00
104	2010, ST	Password	String	Nested loop	Text processing	3	10	0,54
105	2011, NAT	Symmetrical number	String	Nested loop functions	Text processing	9	12	0,14
106	2011, NAT	Maximum profit	dimensional array	Loop syntax, functions	Classification Calculating by a formula	13	8	-0,24
107	2011, NAT	Frequency	String	Nested loop	Text processing	14	9	-0,22
108	2011, WCI	Figures	numbers	Loop syntax, switch	Logical	15	9	-0,25
109	2011, WCI	Game	numbers	Loop syntax, functions	Euclidean algorithm	2	10	0,67
110	2011, WCI	Top results	Two-dimensional array	Nested loop functions	OPT	12	15	0,11
111	2011, NOI2	Letters	Two-dimensional array	Loop syntax	Text processing, BR	18	9	-0,33
112	2011, NOI2	Non-decreasing queue	numbers	Loop syntax	OPT	22	1	-0,91
113	2011, NOI2	The forbidden corridor	dimensional array	Loop syntax	OPT	17	3	-0,70
114	2011, NOI3	A correct word	String	Nested loop functions	Text processing	5	5	0,00
115	2011, NOI3	Code	String	Nested loop	Text processing	2	11	0,69
116	2011, NOI3	Lottery	dimensional array	Nested loop		0	1	1,00
117	2011, NOI3	Points	Two-dimensional array	Nested loop functions		8	5	-0,23
118	2011, NOI3	Numerical triangle	numbers	Loop syntax	SUM[10], OPT	5	2	-0,43

119	2011, NOI3	Super simple	numbers	Nested loop functions	Sieve of Eratosthenes, prime numbers	4	6	0,20
120	2011, ST	Competitors	Two-dimensional array	Loop syntax, functions	Recursion	1	7	0,75
121	2011, ST	"Unusual" fractions	numbers	Nested loop	Euclidean algorithm	3	6	0,33
122	2011, ST	Bank code	Two-dimensional array	Nested loop functions	Complete depletion	1	20	0,90
123	2012, WCI	Alarm	numbers	Nested loop functions	UNIT, classification	7	15	0,36
124	2012, WCI	Young programmer and C++	numbers	Loop syntax	Calculating by a formula, SUM	0	3	1,00
125	2012, WCI	Rectangle	Two-dimensional array	Nested loop functions		13	11	-0,08
126	2012, NOI2	Linden-trees	Two-dimensional array	Nested loop	Calculating by a formula	17	2	-0,79
127	2012, NOI2	Message	Two-dimensional array	Nested loop		15	9	-0,25
128	2012, NOI2	Colored balls	String	Nested loop functions		12	10	-0,09
129	2012, NOI3	Director decides	numbers	Nested loop	Calculating by a formula	10	1	-0,82
130	2012, NOI3	Amount	numbers	Loop syntax	SUM, SWAP	8	1	-0,78
131	2012, NOI3	Crossword	Two-dimensional array	Nested loop		6	5	-0,09
132	2012,NOI3	Gifts	numbers	Nested loop		9	5	-0,29
133	2012, NOI3	Case for Gold	numbers	Nested loop		5	7	0,17
134	2012, NOI3	Number-palindrome	numbers	Loop syntax functions	Number systems	8	6	-0,14
135	2012, ST	Stage numbers	dimensional array	Nested loop		12	8	-0,20
136	2012, ST	Processors	dimensional array	Loop syntax, functions		8	11	0,16
137	2012, ST	Robot	String	Loop syntax, functions, switch		13	5	-0,44
138	2012, NAT	Page number	String	Loop syntax		5	66	0.86
139	139, NAT	Postman	One-dimensional array	Loop syntax, functions		3	68	0.92
140	2012, NAT	Chess board	Two-dimensional array	Loop syntax, functions		13	58	0.63
141	2013, WCI	Corners	Numbers	Conditional operator		41	16	0.44

142	2013, WCI	Riddle	String	Nested loop		14	44	0.52
143	2013, WCI	A park	Two-dimensional string	Nested loop		5	54	0.83
144	2013, NOI2	WOW	One-dimensional string	Loop syntax		33	16	0.35
145	2013, NOI2	Cube colouring	One-dimensional array	Nested loop		13	21	0.24
146	2013, NOI2	TSTSTS-BREH	String	Nested loop		14	29	0.35
147	2013, NOI3	Dates	One-dimensional array	Nested loop, functions		1	15	0,88
148	2013, NOI3	Presenting	One-dimensional array	Loop syntax		10	6	0.25
149	2013, NOI3	Rabbits	One-dimensional array	Nested loop		12	3	-0.6
150	2013, NOI3	Prime numbers	One-dimensional array	Nested loop		2	15	0.76
151	2013, NOI3	Naval engagement	Two-dimensional array	Nested loop, functions		5	10	0.33
152	2013, NOI3	Nine times	Numbers	Nested loop		12	3	-0.60
153	2013, ST	Drawing	One-dimensional array	Loop syntax, functions		0	38	1
154	2013, ST	Lost way	Two-dimensional array	Loop syntax, functions		5	34	0.74
155	2013, ST	Pentagonal numbers	One-dimensional array	Loop syntax		19	22	0.07

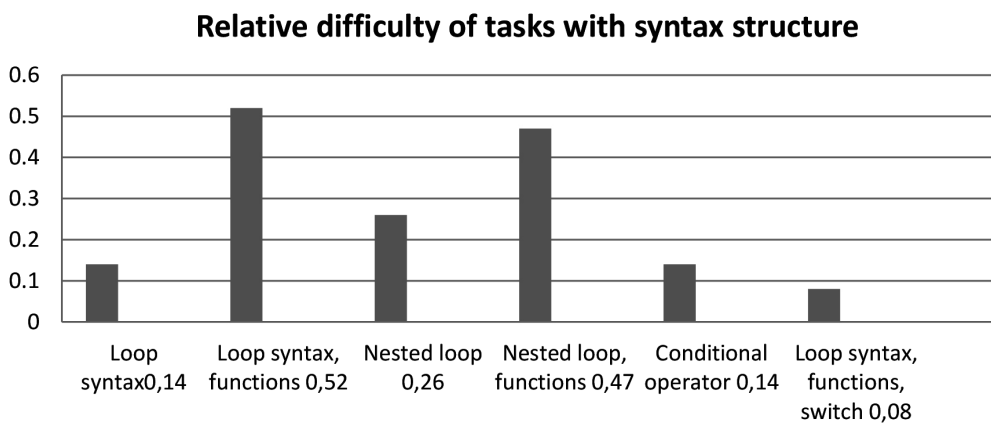

Fig. 4. Relative difficulty of the tasks with syntax structure

Conclusions. There are no difficult tasks in general but tasks, with which students are familiar and have practiced them in school. The others are completely new. Tasks of medium difficulty are those that combine knowledge and different algorithms. The Diagrams (Fig.5 and Fig. 6) show that tasks such as (co-efficient '*k*' is negative) during the last two school years.

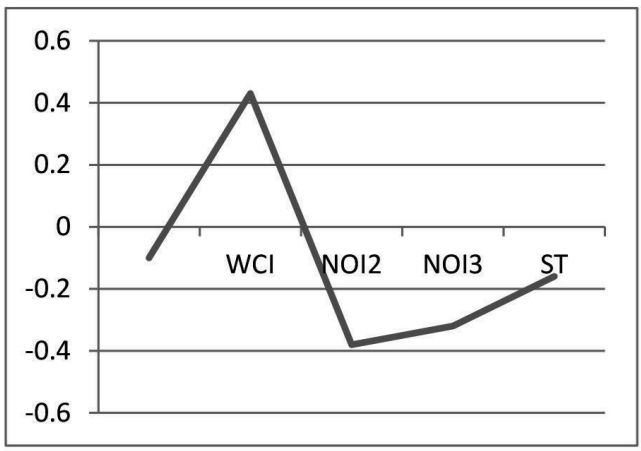

Fig.5. Relative difficulty of the competition tasks for the school year 2011/2012

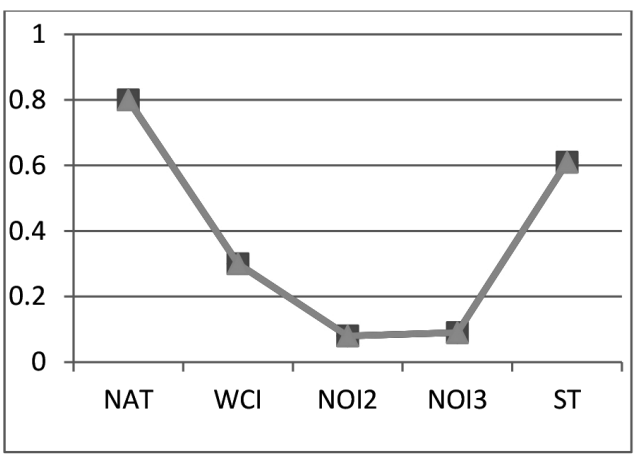

Fig.6. Relative difficulty of the tasks in competitions for the school year 2012/2013

We used all these data for further analysis and classification of the problems which might be useful for the teachers concerned with extracurricular activities as well as self-educating students. The current report will also help the preparation of future competition topics. It is necessary for us to improve the processing of the studied algorithms to achieve better results. To be confident in our success in competitions we need to apply the acquired theory and to put it into considerably more practice.

NOTES

1. http://infoman.musala.com/
2. http://www.math.bas.bg/infos

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