Journal of the Korea Society of Mathematical Education Series D: Research in Mathematical Education
Vol. 12, No. 1, March 2008, 27–37

韓國數學敎育學會誌 시리즈 D: <數學敎育硏究>
제 12 권 제 1 호 2008 년 3 월, 27–37

Test in Algorithm Design and Logics for Competition of Talented Children[1]

Bilousova, Lyudmila I.
Physics and Mathematics Department, Kharkov National Pedagogical University,[2]
Artema Str. 29, Kharkiv, 61002, Ukraine;

Kolgatin, Oleksandr G.*
Physics and Mathematics Department, Kharkov National Pedagogical University,
Artema Str. 29, Kharkiv, 61002, Ukraine; E-mail: Kolgatin@ukr.net

(Received January 18, 2008; Accepted February 4, 2008)

A test as a form of diagnostic of algorithm and logic abilities is considered. Such test for measuring abilities and achievements of talented children has been designed and used at the Kharkiv Regional Olympiad in Informatics. Quality of the test and its items is analyzed. Correlation between the test results of children and their success in creating mathematical models, designing of complicated algorithms and translating these algorithms into computer programs is discussed.

Keywords: Olympiad in Informatics, algorithm design, logics, talented children, test
ZDM Classification: B60, U40
MSC2000 Classification: 97U40

PUPILS' OLYMPIAD IN INFORMATICS

One aspect of the mathematical education is logic and algorithm culture. This field of knowledge is learned as a special subject "Informatics" in the Ukrainian schools. There are special educational competitions in this subject for talented pupils, which are organized in Ukraine every year and are called *Pupils' Olympiads in Informatics.* Since 1988 Ukrainian Olympiad in Informatics was a part of the All-Union Olympiad, which was organized in the Union of the Soviet Socialist Republics (Shakirov, 1987; Vilenkin,

---

[1] This paper will be presented (poster session) at the 13th International Seminar on Education of Talented Children in Mathematics at Soongsil University, Seoul, Korea; February 23, 2008.
[2] named after the Ukrainian philosopher Grigory Savvich Skovoroda
* Corresponding author

1988). Now Ukraine is independent country and these competitions are conducted in such stages: school, district, region and All-Ukrainian (Kreminsky, 2004; Bondarenko, 2006a). The winners of the All-Ukrainian Olympiads take part in the international competitions (Bondarenko, 2006b,). Children compete in creating mathematical models; designing of complicated algorithms and translating these algorithms into computer programs (*cf.* References). On the region-level Olympiads there are two rounds: theoretical and practical. Practical round is devoted to designing of mathematical models, algorithms and computer programs according to offered problems, which are new for pupils. Theoretical round in Kharkiv region was organized as solving problems in test form (Bilousova & Kolgatin, 2005).

There are a lot of international projects, such as PISA (Keitel-Kredit, 2004; OECD, n. d.), TIMSS (Mullis *et al.*, 2005), *etc.*, which show us possibility to research educational achievements and abilities of children with special systems of problems in the test form. However a bank of high-level test problems is not enough for wide using the tests for measuring and comparing of the talented pupils' achievements. So designing of new high-level tests is of current importance. We have some practical experience in design of the problems in test form, which are oriented on the talented pupils and assumes the intellectual activity of high levels: analysis, synthesis and estimation.

The aim of this work is to present the test of theoretical round of the Kharkiv Regional Pupils' Olympiad in Informatics of the year 2004 and analyze its reliability and validity.

THE KHARKIV REGIONAL OLYMPIAD IN INFORMATICS

Since 2001 the Kharkiv Regional Olympiad is conducted in two rounds: theoretical (without computers) and practical (with computers). Theoretical round is the first and its results should be processing in short time: one hour. So the theoretical round is organized as a test. Let us consider the test form, which was suggested to the participants of the Olympiad (*cf.* Appendix). Participants should write-in their answers in frames on the blank form. We have written-in the correct answers in Appendix for easy analysis of the test. The test score of every participant was calculated as a number of correct answers.

STATISTICAL CHARACTERISTICS

Statistical parameters of every item were calculated according to the test results after the Olympiad and are presented in the Table 1. We could not verify our test before the Olympiad, because any disclosure of test contents was inadmissible. However, the most of the items conform to demands of the pedagogical theory of measurements (Avanesov, 2002), so our system of test problems is really the test and can be used for measuring. The statistical parameters (Brown, 1970; Burlachuk & Morozov, 1989) of this test are presented in the Table 2. The histogram on Figure1 shows the distribution of numbers of participants according to their test score.

Table 1. Statistical characteristics of the items

Item Number	Part of the correct answers among the participants			Discrimi-nation index	Pearson Correlation		
	I Round	II Round	All-Ukrainian Olympiad		I Round	II Round	All-Ukrainian Olympiad
1	0.24	0.43	0.64	**0.33**	**0.40**	0.20	-0.01
2	0.23	0.56	0.91	**0.48**	**0.53**	0.28	**0.35**
3	0.84	0.93	0.91	0.15	0.18	0.00	0.14
4	0.15	0.43	0.45	**0.30**	**0.48**	0.16	0.19
5	0.38	0.81	1	**0.67**	**0.60**	0.29	–
6	0.16	0.50	0.73	**0.43**	**0.59**	**0.31**	**0.30**
7.1	0.44	0.69	1	**0.47**	**0.40**	0.07	–
7.2	0.01	0.02	0.09	0.01	0.14	0.28	**0.57**
8.1	0.29	0.76	0.82	**0.63**	**0.61**	0.05	0.29
8.2	0.18	0.63	0.64	**0.47**	**0.63**	0.22	**0.68**
9.1	0.72	0.98	1	**0.56**	**0.50**	0.08	–
9.2	0.30	0.59	0.64	**0.43**	**0.44**	0.25	**0.58**
9.3	0.55	0.94	0.91	**0.69**	**0.55**	0.16	**0.30**
9.4	0.48	0.93	1	**0.68**	**0.58**	0.19	–
10	0.07	0.15	0.09	0.06	0.15	-0.08	-0.14
11.1	0.40	0.81	0.91	**0.41**	**0.46**	0.20	**0.4**
11.2	0.12	0.33	0.73	**0.25**	**0.47**	**0.46**	**0.47**
11.3	0.24	0.54	0.82	**0.46**	**0.50**	**0.42**	**0.52**
12	0.14	0.26	0.45	0.12	0.25	0.27	**0.61**
13	0.14	0.30	0.45	0.15	0.23	0.03	0.40
14.1	0.28	0.59	0.55	**0.59**	**0.50**	-0.20	-0.40
14.2	0.48	0.96	1	**0.83**	**0.67**	0.12	–
14.3	0.17	0.44	0.73	**0.41**	**0.53**	**0.37**	**0.51**
15	0.24	0.50	0.45	**0.36**	**0.37**	0.00	-0.4

Table 2. Statistical characteristics of the test

Number of the first (theoretical) round participants	241
Number of the second (practical) round participants	54
Number of items (maximal possible score)	24
Average score	7.2
Lowest observed score	0
Lowest second round passing score	11
Maximal observed score	21
Variance	21.0
Split-half reliability (Brown, 1970)	0.82
Internal consistency (Cronbach Alpha) (Burlachuk & Morozov, 1989)	0.84
Pearson correlation between the scores of the test and practical round	0.61
Pearson correlation between the scores of the test and All-Ukrainian Olympiad (11 participants)	0.76

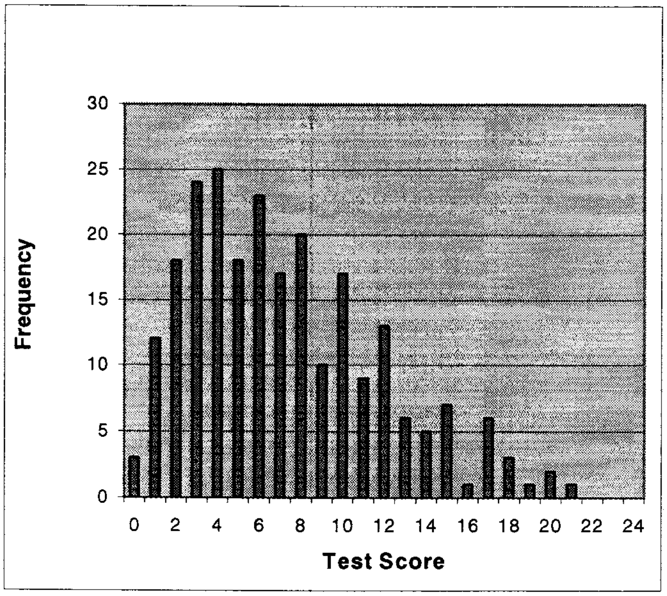


Figure 1. Histogram of the distribution of frequency of the test score obtained by Olympiad participants

The test reliability is satisfactory. Since the range of test scores is wide (Figure 1), so the test contains problems of different difficulties and is suitable for measuring in wide diapason of Olympiad participants' skills. The test results correlate with results of the practical round of the Olympiad (Table 1) that verifies its validity. In the year 2004 we had unique possibility to verify correlation of the test results with results of All-Ukrainian Olympiad (Kreminsky, 2004), because the Kharkiv team on the All-Ukrainian competetion consisted of 11 children. The correlation was found to be 0.76 that is quite excellent. It is interesting that correlation between the results of the practical round of the Kharkov regional Olympiad and the results of the All-Ukrainian Olympiad was 0.68 which is not more than that of our test score. So we can say that test possesses the prognostic validity in designing of non-standard mathematical models and algorithms. The problems, which provide such correlation, are connected with the intellectual activity on a research level and correspond to a high level of educational achievements.

Let us analyze test items in detail. Most of them have excellent discrimination index (bold font in Table 1). Such items have the most excellent discrimination index: 5, 8.1, 9.1, 9.3, 9.4, 14.1, and 14.2. Five of twenty four problems do not have good discrimination. Let us discuss their role in the test.

Discrimination index of the item 3 is 0.15 (not good). It proved to be too easy. Perhaps the participants chose the correct answer by intuition and did not analyze the methods of information compression as the authors assumed.

The item 7.2 proved to be too difficult. Only two children answered correctly. One of them, Dmitro Djulgakov, became the best in the Krarkiv team at the All-Ukrainian Olympiad in 2004 (Kreminsky, 2004) and won the silver medal at the International Olympiad in Informatics (IOI)[3] in 2006 in Mexico (Bondarenko, 2006b). So this item possesses good prognosis validity and is an important element of the test.

The item 10 is also complicated. Combination of several problems in one item could decrease participants' attention and lead to mistakes of pupils with high qualification. Such item can not be a test item. This problem may be posed to pupils at facultative learning to demonstrate, that algorithms can be similar for some input data, but differ in special case of input data. Some of presented algorithms produce equivalent values of the variable k in most cases, and its result differ only in case of absence of positive elements in the array.

The item 12 proves to be difficult for most of 241 participants of the first (theoretical) round. Its correlation with the test score is 0.25, which is not quite good. This item examines logically thinking ability rather than ability to design algorithms. However it

---

[3] International Olympiad in Informatics (an official website): www.ioinformatics.org
Website (related to or endorsed by the IOI): http://olympiads.win.tue.nl/ioi/

possesses high and statistical significant validity for result of All-Ukrainian Olympiad.

The item 13 is also difficult and demonstrates low discrimination for participants of the first round of the Olympiad, but good correlation with results at All-Ukrainian Olympiad for the best 11 participants. This correlation is good (0.40) but number of cases is not enough for a reasonable conclusion.

Every item provides good diagnostic ability in a bounded range of pupils' educational achievements only. If qualifications of pupils differ in a wide range, various items work for different groups of pupils. For example, the item 14.2 is leading problem of the test with discriminations index 0.83 for all participants of the fist round, but one is very easy for the best 54 participants, who take part in the second round, and do not provide the prognosis of the second round result. Otherwise the items with the most creative problems, which are the best for prognosis of the result at the All-Ukrainian Olympiad, is often very difficult for the most regional Olympiad participants and so this items do not provide good discrimination (for example, items 7.2 and 12). Unique items 2, 6, 8.2, 9.2, 9.3, 11.1, 11.2, 11.3 and 14.3 keep discrimination ability in all range of participants' educational achievements and provide the prognosis of the All-Ukrainian result at the same time.

Now we can select items for the modernized test and arrange them by difficulty in ascending order: 9.1; 9.3; 9.4; 14.2; 7.1; 11.1; 5; 9.2; 8.1; 11.3; 2; 8.2; 14.3; 6; 4; 12; 11.2; 7.2. This test includes 18 items, which provides reliability 0.82 and prognostic validity for the All-Ukrainian Olympiad result as 0.88.

CONCLUSION

The test for measuring the logic and algorithm abilities and achievements of talented children is designed and verified during the Kharkiv regional Olympiad in Informatics. Correlation of the test score with the results of the 17th All-Ukrainian Olympiad in Informatics is 0.76, so the test is valid. Every test problem provides diagnostics in a bounded range of pupils' educational achievements and creative ability. Selection of the test items according its statistical characteristics improves the test validity for the All-Ukrainian Olympiad result.

REFERENCES

Avanesov, V. S. (2002). *Design of Test Problems* (in Russian). Moscow: Centre of Testing,

Bilousova, L. I. & Kolgatin, O. G. (2005). Problems of the Theoretical Round of the Kharkiv Regional Olympiad in Informatics of the 2004 Year. *Computer at School and Family* **2005(6)**, 47–51.

Bondarenko, V. V. (2006a). 19th All-Ukrainian Olympiad in Informatics (in Ukrainian). *Computer at School and Family* **2006(3)**, 49–50.

_____ (2006b). 18th International Olympiad in Informatics (in Ukrainian). *Computer at School and Family* **2006(6)**, p. 53.

Bondarenko, V. V.; Porublev, I. M.; Rublev, B. V.; Tkachuk, V. L.; Yagiyaev, S. I. & Yakovenko, B. V. (2004). Problems of the 17th All-Ukrainian Olympiad in Informatics (in Ukrainian). *Computer at School and Family* **2004(4)**, 38–41, **2004(5)**, 44–49.

Bondarenko, V. V.; Stasyuk, O. V.; Porublev, I. M.; Yagiyaev, Sh. I. & Yakovenko, B.V. (2005). Problems of the 18th All-Ukrainian Olympiad in Informatics (in Ukrainian). *Computer at School and Family* **2005(3)**, 42–45.

Bondarenko, V. V.; Tkachuk, V. L. & Yagiyaev, Sh. I. (2006). Problems of the 19th All-Ukrainian Olympiad in Informatics (in Ukrainian). *Computer at School and Family* **2006(3)**, 44–48.

Brown, Frederic G. (1970). *Principles of Educational and Psychological Testing.* Hinsdale, IL: Dryden Press, 1970.

Burlachuk, L. F. & Morozov, S. M. (1989). *Vocabulary — Reference Book on Psychology Diagnostics* (in Russian). Kiev: Naukova Dumka.

Gurgiy, A. M. & Bondarenko, V. V. (2006). Problems of the 18th International Olympiad in Informatics and Recommendations on its Solving (in Ukrainian). *Computer at School and Family* **2006(7)**, 47–50, **2006(8)**, 43–47.

Keitel-Kredit, C. (2004). The shaping of mathematics education through testing. In: *Proceedings of the 10th International Congress on Mathematical Education (ICME-10) held at Copenhagen, Denmark, July 4–11, 2004. Volume "Plenary and Regular Lectures"* (pp. 64–65).

Kreminsky, B. G. (2004). 17th All-Ukrainian Olympiad in Informatics (in Ukrainian). *Computer at School and Family* **2004(3),** 50–52.

Mullis, Ina V. S.; Martin, Michael O.; Ruddock, Graham J.; O'Sullivan, Christine Y.; Arora, Alka & Erberber Ebru (2005). *TIMSS 2007 Assessment Frameworks.* Chestnut Hill, MA: TIMSS & PIRLS International Study Center. ERIC ED494654 Available at: http://isc.bc.edu/TIMSS2007/PDF/T07_AF.pdf or www.eric.ed.gov/ERICWebPortal/contentdelivery/servlet/ERICServlet?accno=ED494654

OECD (n. d.). *PISA Sample Questions.* Camberwell, VIC, Australia: Australian Council for Educational Research. Available at: http://pisa-sq.acer.edu.au/

Shakirov R. M. (1987). The 1st All-Union (USSR) Pupils' Olympiad in Informatics (in Russian). *Kvant.* **1987(11)**, p. 30, 56.

Vilenkin, A. N. (1988). The 1st All-Union (USSR) Pupils' Olympiad in informatics (in Russian). *Kvant.* **1988(11)**, 82–84.

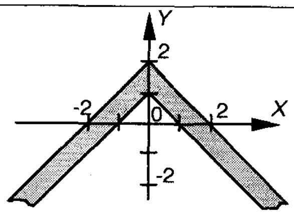
APPENDIX

TEST OF THE THEORETICAL ROUND OF THE KHARKIV REGIONAL OLYMPIAD IN INFORMATICS

1. Quantity of different binary codes with length from 1 to 4 bit is... **[30]**

2. A length of a pixel colour code has been increased on 1 byte after modernisation of a computer. As a result the number of colours of a graphic palette has been changed... 256 times more

3. The file that will have the biggest length after packing by WinZip archiver. **[C]**
   A)AAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAA AAAAAAAAAAA
   B)АБАБАБАБАБАБАБАБАБАБАБАБАБАБАБАБАБАБАБ АБАБАБ
   C)ЙРОУГГГНАТІВДАЩЗЖІЗЛЬЧСТИНМСЕУКХЗШХЗЇІОУНГЦНЕ ІРСІВ
   D)AAAAAAAAAAAAБAAAAAAAAAAAБAAAAAAAAAAAБAAA AAAAAAAAAA

4. 

   This logical expression should be "true" for coordinates of shaded area points and "false" for other coordinates. *Write-in missing operations*

   [(y ≤ x+2) **and** (y ≤ 2-x)] **and** [(y [≥] x+1) [**or**] (y [≥] 1-x)]

5. A hexadecimal digit that is replaced by the character "?" in this equation: $3?A_{(16)} + 9?7_{(16)} = CB1_{(16)}$ **[5]**

6. Design an algorithm that moves the last element of an array A[1..N] to position M with keeping the order of other elements. *Match letters of statements with their order in algorithm.*

   A) A[k]:=A[k+1];
   B) A[k+1]:=A[k];
   C) A[N-k]:=A[N-k+1];
   D) A[N+2-k]:=A[N+1-k];
   E) A[N+1-k]:=A[N-k];
   F) **For** k:=1 **to** N-m **do**
   G) **Begin**
   H) **End;**
   I) A[m]:=X;
   J) X :=A[m];
   K) A[N]:=X;
   L) X :=A[N];

1	L
2	F
3	G
4	E
5	H
6	I

7. *Write-in the missing statements if necessary:*

7.1. This algorithm should produce a natural number N as a product of prime factors.

```
k := 2;
While N>1 do
begin
If N mod k =0 then
begin
        N := N div k;
write (k,' ');
[no statement]
end
else k := k+1
end;
```

7.2. This algorithm should find the number of an element X in an ascending ordered array $A[1..N]$.

```
 L := 1;   V:= N; FL := 0;
While (V>=L) and   (FL=0) do
begin
        k := (L+V) div 2;
        If A[k] = X Then
              FL := 1
         Else
            If A[k] >X   Then  [V := k – 1] Else
                                            [L :=   k + 1]
end;
If FL = 1 Then
Write (k)
Else
        Write ('not found');
```

8.

```
Function F(A,B: integer):integer;
Begin
   If A>B Then F:=F(A–B,B)+1;
   If A<B Then F:=F(A,B–A)–1;
   If A=B Then F:=0;
End;
```

8.1. Write-in F(3,7). [0]

8.2. Write-in F(500,5). [99]

9. *Match:*

Statement

1. **For** k:=1 **to** n **do** x := x + 1;
2. **For** k:=1 **to** n **do** x := x * x;
3. **For** k:=1 **to** n **do** x := x + x;
4. **For** k:=1 **to** n **do** x := 2 *x + 1;

Function that is calculated

A) $x^{(2^n)}$ E) x^n

B) $(x+1)^n$ F) x^{2n}

C) $x+n$ G) $2^n(x+1)-1$

D) $x \cdot 2^n$ H) $2^n(x+1)$

1	C
2	A
3	D
4	G

10.	There is an array T[1..N]. *Choose* algorithms that equally calculate the value of variable *k*	A) *k* := 0;
		For i:=1 **To** n **Do**
		Begin
		If T[i] > 0 **Then**
		k:= i
		end;
			B) k := 0;
			For i:=n DownTo 1 Do
			Begin
			If T[i] > 0 **Then**
			k:= i
			End;	

	C) k := 0; i :=1;
	While (k=0) **and** (i ≤ n) **Do**
	Begin
	If T[i] > 0 **Then**
	k:= i
	Else
	i := i +1
	End;
		D) i := 1;
		While i ≤ n **Do**
		Begin
		If T[i] > 0 **Then**
		i := n + i
		Else
		i := i + 1
		End;
		k := i – n
			E) FL := 0; k := 0;
			While (FL=0) **and** (k<n) **Do**
			Begin
			k := k+1;
			If T[k] > 0 **Then**
			FL := 1
			End;
				B, C

11.	There is an algorithm of function with an omitted statement:
	Function F(n:integer):integer;
	Begin
	If n > 0 **Then**
	....
	Else F := 1
	End;
		Match:
		Function that is calculated
		F(n) = $2^n n!$
		F(n) = (2n)!
		F(n) = 1·3·5·...·(2n-1)
			Omitted statement in algorithm
			A) F := F(n–1)*2*n*(2*n–1)
			B) F := F(n–1)*2*n
			C) F := F(2*n–1)*2*n
			D) F := F(n–1)*(2*n-1)
			E) F := F(n–2)*(2*n–1)
				1 B
				2 A
				3 D

12.	There are 4 cards with a symbol on its faces: A, B, 4, 5. There is any symbol on each card back. Which cards should you turn over to check a verity of the thesis:"If vowel letter is on one card side then an even number is on other card side"?		*Choose correct answers* а) A, B, 5 б) B, 4, 5 в) A, B, 4 г) A, 4, 5	a
13.	*Choose* algorithms which execution on a computer leads to infinite looping			

	а) S := 1; X :=1;
	While X > 0 **Do**
	Begin
	X := X / 2;
	S := S + X
	End
		б) X :=1; Y :=3*X;
		While Y > 0 **Do**
		Begin
		Y := Y – X;
		X := X / 2
		End
			в) X1 := 1/2; X2 := 1 + X1;
			While |X2 – X1| > X1 / 2 **Do**
			Begin
			X1 := X2 – X1;
			X2 :=X1 + 1
			End
				б,в

14.

An input matrix is

T=

x	o	x
o	x	o
x	o	x

Fill the matrix which will be obtained after this algorithm has been executed

14.1

```
For i:=1 To 3 Do
begin
j :=1;
While T[i,j] <> "o" Do
Begin
T[i,j] :="o";
j := j + 1
End
End
```

T=

o	o	x
o	x	o
o	o	x

14.2

```
For i:=1 To 3 Do
Begin
j :=1;
While T[i, j] <> "o" Do
Begin
j := j + 1;
T[i,j] :="o"
End
 End
```

T=

x	o	x
o	x	o
x	o	x

14.3.

```
For i:=1 To 3 Do
Begin
For j:=1 To 3 Do
Begin
If T[i,j] ="x" Then
T[i,j] :="o";
If T[i,j] ="o" Then
T[i,j] :="x"
End
End
```

T=

x	x	x
x	x	x
x	x	x

15

A customer of an automatic cash terminal may do 3 attempts to enter a secret code. The Card is seized if the third attempt is unsuccessful.
Match omitted statements with its places in this algorithm:

k := 0
Request of secret code (x)
....
....
Continue to serve a customer

Statements:
а) **If** x="code" **Then Goto** 5
б) **If** k < 3 **Then Goto** 2 **Else** "Seize the card, break to serve"
в) **If** (k < 3) **and** (x ≠ "code") **Then** k := k+1; **Goto** 2 **Else** "Seize the card, break to serve"

г) **If** x = "code" **Then Goto** 5 **Else** k := k+1
д) **If** k ≤ 3 **Then Goto** 2 **Else** "Seize the card, break to serve"
е) Blank statement

3	г
4	б