Bebras International Contest on Informatics and Computer Literacy: Criteria for Good Tasks

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Abstract. The Bebras International Contest on Informatics and Computer Literacy is a motivation competition in informatics that addresses all lower and upper secondary school pupils divided into three age groups: Benjamin (age 11-14), Junior (age 15-16) and Senior (for upper secondary level). Using a computer the pupils have to solve 15 to 21 tasks of different levels within 45 minutes. Two general types of problems have been used: interactive tasks and multiple-choice tasks. Creating interesting and attractive tasks that are also motivating and funny for the pupils is very challenging. The paper deals with criteria for good tasks. Some examples of tasks are presented and discussed as well.

Keywords: Teaching informatics, Computer education, Contest on computer literacy, Developing tasks.

1 Introduction

The quality of tasks is crucial for the success of all task-based competitions. Usually competitions have several goals and the tasks have to fulfill a wide variety of criteria. The tasks must reflect the goals of the competition and should be adequate for the applicants. Seeking to motivate students to learn science issues more deeply competitions are one of the best ways to capture their attention [3, 4, 12]. In educational competitions, tasks should attract students and drive them to learn and explore as well to develop skills in the particular area [6]. Children are attracted by competitions and get easier involved in discussions and become more active [11].

The Bebras International Contest on Informatics and Computer Literacy addresses pupils grade 5 to 12 (13 in some countries) and aims to motivate the participants to be interested in typical informatics problems. The Bebras Contest has a similar structure as the Kangaroo Contest in the field of Mathematics [9]. The students have to solve a series of tasks of three different difficulty levels. Each task takes between 1 to 4 minutes to be solved. Finding interesting and adequate tasks that can be solved in a few minutes seems to be much harder in the field of informatics than in the field of Mathematics. This paper shows criteria for good tasks and gives examples for good task development.

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2 Experiences of the International Bebras Contest

The idea of the International Bebras Contest on Informatics and Computer Literacy originated in Lithuania 2003 (The name Bebras – in English "beaver" – is connected with the hard-working, intelligent, goal seeking and lively animal living around lakes and rivers in Lithuania and other countries). It took almost a year to create tasks and to prepare technology to implement it: the first contest started in October 2004. The organizers had the goal to make the Bebras Contest an international one. The well-known Baltic Olympiad in Informatics was organized in Lithuania in May 2005 [1]. It was a good opportunity to advertise the Bebras Contest at least for participants of the Olympiad (Denmark, Estonia, Finland, Germany, Latvia, Sweden, and Poland). During the Baltic Olympiad the international Bebras workshop for creating tasks was organized. Four more countries were invited and participated in the Bebras workshop (Austria, Egypt, Israel, and The Netherlands). Participants spent a lot of time discussing the structure and development of the contest as well as preparing tasks. It was decided to run the Bebras Contest each autumn (October-November).

In spring 2006, the second International Bebras Contest workshop was organized in Lithuania and the International Bebras Organizing Committee was established [8]. The main goal of the workshops is to develop a set of tasks for the coming Bebras Contest. After a year the third international Bebras workshop was organized again in the same place as previously. Two more countries joined the workshop: Slovakia and Ukraine.

At the moment some countries have already been running the international Bebras contest for their pupils, some are still in a preparation stage. In 2007, the Bebras Contest was very successful in Germany – 21 802 participants (www.informatik-biber.de), in Estonia – 2978 participants (www.miksike.ee), as well as in Lithuania – 7015 participants [8], in Poland – around 7000 participants (www.bobr.edu.pl), in the Netherlands – 2405 participants (www.beverwestrijd.nl), in Austria – 1400 participants (http://at.beverwedstrijd.nl/).

3 Categories of Tasks

Children and students are using computers and technology every day. Some of them have a better understanding, other are plain users. However users need also some thinking skills while applying technology. The best way to develop thinking skills is to solve problems. The ability of pupils to solve problems in real-life settings is of prime concern to educators and policy makers. Interest and engagement are very important in problem solving [3, 5].

Problem solving is an individual's capacity to use cognitive processes to confront and resolve real, cross-disciplinary situations where the solution path is not immediately obvious [2].

When teaching informatics and computer literacy via problem solving, it is very important to choose interesting tasks (problems) for motivating learning. Therefore, one should try to present problems from various fields of science and life, with a lot of real data.

Interest in competitions essentially depends on problems. Attraction, invention, tricks, surprise should be desirable features of each problem presented to competitors. The problems have to be selected carefully, taking into account the different aspects of each problem, i.e. what educational power it contains and how to interpret its attractiveness to students (whether it stimulates the motivation of learning).

Problems can be of different types: starting from the most common questions of computers and their applications in the daily life to specific integrated problems related to history, languages, arts, and, of course, mathematics. It is very important to choose the problems in such a way that the participants of the competition could have the same chance to solve the tasks, irrespective of the operating system or computer programs used by them.

In informatics, there is also the problem of syllabus. Even if there is an education standard for informatics at school in some countries, there till now there is no common agreement what should be included in an integrated syllabus using information technologies. We can use some guidelines e.g. the UNESCO recommendations [7].

In the first and second international Bebras contests some problems were related to the usage of various most common programs, others were related to hardware and software, and some of them were connected with the culture and language. So it could happen that some problems would not be applicable in some countries: some might appear too simple, and some – too complicated.

At the second international Bebras workshop (2006), a brainstorming session was held to generate ideas for different types of tasks that could be used in the contests. Also the classification of tasks was started to elaborate and some topics groups were suggested [10].

The classification proceeded further in the third Bebras workshop and in discussions between members of the Bebras Organizing Committee. In September 2007, some active members of the Bebras Organizing Committee have launched the meeting in Potsdam and elaborated the following proposal for topics of the Bebras contests on informatics and computer literacy.

INF	**Information comprehension**
	Representation (symbolic, numerical, visual)
	Coding, encryption
ALG	**Algorithmic thinking**
	Including programming aspects
USE	**Using computer systems**
	e.g. search engines, email, spread sheets, etc.
	General principles, but no specific systems
STRUC	**Structures, patterns and arrangements**
	Combinatorics
	Discrete structures (graphs, etc.)
PUZ	**Puzzles**
	Logical puzzles
	Games (mastermind, minesweeper, etc.)
SOC	**ICT and Society**
	Social, ethical, cultural, international, legal issues

This list of task categories improves the task types given in [10] in the respect that it forms a small number of groups of tasks of nearly the same importance and gives the categories names that are easily understandable even by pupils.

The selection of tasks is very important: a set of tasks must cover as many sub-areas of informatics as possible, including algorithms and programming methods, and what is most important, the pupils should acquire the skills of using them. The problems have to be selected taking into account the different aspects of each problem. Two large groups of problems were distinguished: 1) interactive problems (for making something with computer and technologies); 2) multiple choice questions.

The problems have to be selected carefully, with regard to different aspects of each problem (*i.e.*, what educational power it has) and interpretation of its attractiveness to pupils (whether it stimulates the motivation of learning).

4 Criteria for Good Bebras Tasks

The following list of criteria reflects the experiences of the International Bebras Organizing Committee in developing successful Bebras tasks:

Table 1. Criteria for good Bebras tasks on informatics and computer literacy that are used by the International Bebras Organizing Committee. The criteria that start with the word "should" may be not fulfilled by all Bebras tasks.

Good tasks …	***Explanation***
are related to informatics, computer science or computer literacy	As stated in the aims, the Bebras contest is a competition on informatics and computer literacy.
allow learning experiences	In solving the tasks one should learn something interesting. Learning gives satisfaction and is never boring.
can be solved in 3 minutes	3 minutes is the average time to solve a task.
have a difficulty level (3 levels)	Level A (1/3): simple, all pupils of the target group should be able to solve. Level B (1/3): intermediate, challenging tasks that need some thinking to solve. Level C (1/3): hard to solve, only the best can solve these tasks.
are adequate for the age of contestants (3 age groups)	Bebras has 3 age groups: • Benjamin: grade 5 to 8, • Junior: grade 9 to 10, • Senior: grade 11 to 13. Some tasks may be suitable for more than one age group. They may differ in difficult level.
are independent from any curriculum	The International Bebras Contest cannot support all curricula of a large number of countries. The Bebras tasks are oriented on the usual ability of pupils of the addressed age groups.

Table 1. (*continued*)

Good tasks …	***Explanation***
are independent from specific IT systems	Of course all tasks don't rely on pre-knowledge of details of specific IT systems. No specific operating system, programming language or application software is taken for granted. All system specific terms must be explained within a task.
have easy understandable problem statements	A problem statement should be presented as easy as possible: easy understandable wording, easy understandable presentation of the problem (maybe use of pictures, examples, embedded in a proper story, use of a simulation or an interactive solving process), a problem statement should never be misleading.
are presentable at a single screen page	A single task should never exceed a single screen page. Scrolling is not reasonable in a contest situation.
are solvable at a computer, without other hardware, additional software or paper and pencil	Bebras tasks are independent from specific operating or application systems. Use of additional software should not be necessary. Also a calculator should not be necessary to use. Mental arithmetic should be sufficient for all calculations. Cheating is much easier within a computer lab if paper and pencil is allowed.
are politically correct	Good tasks contain no gender, racial or religious stereotypes.
should be funny	Some sort of excitement or fun should be provoked by a good task or by solving the task. It should never be boring.
should have pictures	Tasks that involve pictures are more attractive. The pictures should play a role in understanding or solving the task. It should not be a mere illustration. Pictures are supporting visual thinking.
should have interactive elements (simulations, solving activities, etc)	Multiple-choice is in many cases not adequate. Sometimes it is appropriate to input a number or a word or have a choice of a list of possibilities. Often the result can be produced by operating a simulation of a machine that should be operated properly.
should give immediate feedback	After solving a task correctly the participant should have the certainty of having solved the task correctly.

Furthermore a good Bebras task should not be tricky. A tricky task is usually too hard to be solved by thinking, but the knowledge of a very specific detail allows the solution.

To discuss this list of criteria we give some examples of tasks that were given at beaver competitions. The first one lacks some of these criteria, the others are almost perfect.

4.1 Example Task: Tomorrows Weather

We consider the following multiple choice task:

Assume that the weather would follow the rule:

"If there is a sunny day, the day after will be sunny too"

If it is sunny today, what could you infer?

A. *It is always sunny*
B. *Yesterday it was sunny*
C. *From now on it will always be sunny*
D. *It will never be sunny again*

(One of the answers is correct)

Fig. 1. The Tomorrows Weather task that was given at Bebras contest 2007

At the first glance it seems that this task is a pure logic thinking question, but the requested sort of thinking is exactly the same as it is necessary to understand loops in algorithms and programs. Therefore the task category is partly algorithmic thinking (ALG) and partly puzzles (PUZ) because of its logical puzzle characteristic. If one is not sure that C is the correct answer it should be possible to exclude the wrong answers by falsification of the answers A, B and D.

This task does not fulfill all optional criteria for good tasks:

- It has no picture involved
- It has no interactive elements

In the Bebras competition 2007 in Austria this task (a German translation) was used in the age groups Benjamin and Senior. In both age groups it was the task with the highest number of wrong answers.

Due to this fact we can say that also some other criteria are not completely fulfilled:

- It is not funny (interesting) to solve the task (what is funny when the idea of the task was not grasped by so many pupils?)
- The problem statement is not easily understandable (maybe there were problems to understand the term "infer")
- It does not allow enough learning experiences (what can be learned when nearly all participants failed to solve the task?)

Due to this list of not fulfilled criteria it is now - after the competition - questionable if this was really a good Bebras task.

The Weather task yielded also another interesting result: it was the only task that had more correct solutions in the younger group (22%) than in an elder group (10%). It is very surprising that it was this logic oriented task that was easier for the younger pupils to find the correct solution.

4.2 Example Task: Islands in a Lake

Now we give an example of a possibly perfect interactive task:

> *Beaver discovered a number of islands in a lake and decided to build bridges to connect them. While building bridges Beaver follows the rules: the bridges must be built keeping the directions East-West and North-South and they shouldn't overlap each other.*
>
> *Help Beaver to build as many bridges as possible. Use the mouse to connect pairs of islands.*

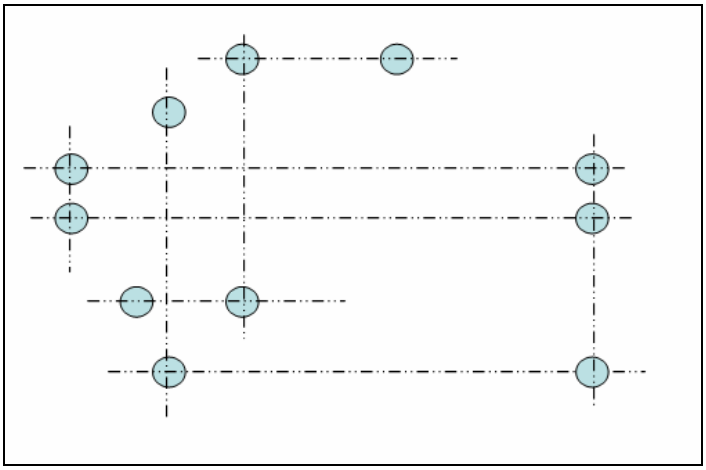

Fig. 2. An interactive task, age group Junior, difficulty level A (simple)

It is an algorithmic thinking (ALG) task, since a solution strategy incorporates strategies to find all different ways of building bridges. The possibility of interactively building bridges that are counted automatically and that can also be reset allows a sort of game-based learning.

4.3 Example Task: Shape Manipulation

Anne created a program, which includes just three operations:

- *rotation of the shape 90 degrees to the right*
- *rotation of the shape 90 degrees to the left*
- *mirroring of the shape*

These operations can be performed unlimitedly.

Which one of these shapes is IMPOSSIBLE to attain while experimenting with the given shape?

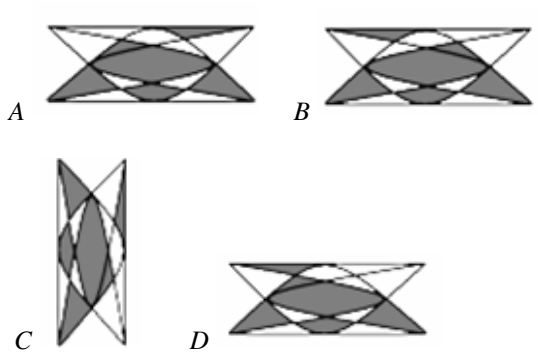

Fig. 3. A multiple choice task, age group Benjamin, difficulty level C

This multiple choice task does not involve any interactive elements. The challenge in this task is not doing but imagining the possible effects of the operations. It is a way of thinking that is also necessary in testing software.

5 Challenges for the International Bebras Task Development

Each year the international Bebras workshop develops a set of new tasks and questions. The group of international experts in pedagogy and computer science follows a process that allows creativity in finding new tasks and ensures a high quality of the output. It is not easy to create tasks that fulfill all criteria. Even the mandatory criteria are often hard to meet. But all tasks that do not fulfill the mandatory criteria have to be dropped. Often it is a process of several versions from an imperfect task formulation to an acceptable formulation.

The mandatory criteria that are usually hard to meet are:

- the task can be solved within 3 minutes
- the problem statement is easy understandable
- the task is presentable at a single screen page
- the task is solvable at a PC without use of other SW or paper and pencil
- the task is independent from specific systems

Practical tasks in informatics are usually not solvable within 3 minutes. So the tasks for the Bebras contest have to concentrate on smaller learning items. Due to the independence from specific systems the focus of the tasks is not the work in real systems but the understanding of the principles, ideas and concepts that are involved in informatics systems.

The easy understandability of tasks is in all contexts a very important goal. Not only the wording but also the presentation of the task that may include interactive elements is important. Since the pupils should be able to solve a task in an average

time of 3 minutes, the formulation of a task should be as short as possible but at any rate no longer than a single screen page. Since the Bebras contest is performed at PCs there should be no need for paper and pencil to solve a task. It should not be easier to solve a task on paper than without paper. Usually it is possible to provide suitable interactive elements on the PC so that a solution on the PC is easier.

Of course the desirable criteria are much harder to meet; two of them are discussed here:

- should be funny,
- should have interactive elements

What is funny differs from person to person. But it is important that the authors of the tasks think about the possible feelings of the pupils when they are confronted with the tasks. The Bebras Contest should motivate the pupils to be interested more deeply in informatics. This goal can only be reached if the tasks are interesting and provoke some excitement. Pure knowledge tasks are often not as exciting as tasks where thinking is necessary to solve them. Most of the Bebras tasks give new situations the pupils have never seen before, so thinking is the only way to find the correct solution.

The interactivity is very typical for computers, so it is clear that a computer oriented contest should apply interactive elements to explain or solve tasks. Very often these interactive elements are "funny" to use and make the understandability of the problem statement much easier.

Especially the interactive elements need a lot of effort in the implementation of the tasks. But due to the attractiveness of interactive tasks the high effort for implementing the interactive part is worth to be done.

6 Example of a Task Development

Now we describe the development of a task from the initial idea for that task to an intermediate, not satisfactory state to the final formulation.

6.1 Idea for a Data Structure Task and First Formulation

At the beginning was the idea for a task that involves the data structure "Heap". For a given binary tree with values at the nodes we wanted to ask how many exchanges of values are necessary to achieve a "Heap".

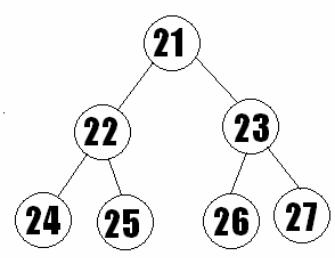

Fig. 4. The binary tree that should be transformed to a "Heap"

Since we cannot expect that the addressed pupils are familiar with the data structure of a "Heap" we had to give a definition of a "Heap".

> *The picture shows a binary tree with values in the nodes. A binary tree is called a "Heap" if each parent node has a value greater than or equal to both child nodes. The given binary tree is not a "Heap". Give the minimum number of value exchanges (of any two nodes) that produces a "Heap".*
>
> *Answers: A) 2 B) 3 C) 4 D) 5*

Fig. 5. The first formulation of the Heap task

This formulation requires pre-knowledge of the graph theoretical terms "node" and "binary tree", so this task may be suitable only for pupils of the senior age group.

The main problem with this task is that it is not easy understandable. There is only a textual definition of a "Heap"; an example of a "Heap" may be very useful. If we would use an example with other values than the given binary tree, the problem description would be extremely lengthy and the presence of two different trees would possibly be disturbing and misleading. If we would present the final Heap with the values at the final positions of the given tree, this task would be understandable and very easy to solve but there would be no learning about the "Heap" data structure possible.

As we found the idea of this task very interesting and suitable for the Bebras contest we had to work on a better presentation of this task.

6.2 Final Formulation with the Technique of Telling a Suitable Story

Finally we tried to find a suitable story that makes the understanding of a "Heap" more intuitively and more easily. The idea for the story was "to take a group photo of the young beavers". This led to the final formulation of the Beaver's Group Photo task:

> *To make a group photo of 7 beavers it is necessary that the smaller beavers stand in front and the larger beavers in back. Unfortunately the beavers stand in a wrong order. In the graphics below those beavers are connected by a line where the back beaver should be larger than the front beaver. The only operation to rearrange beavers you can do is exchanging any two beavers of the group.*
> *What is the minimum number of exchange-operations, that after all, the beavers are ready for taking picture?*
> *Please perform a minimum number of exchange-operations by clicking on pairs of beavers.*

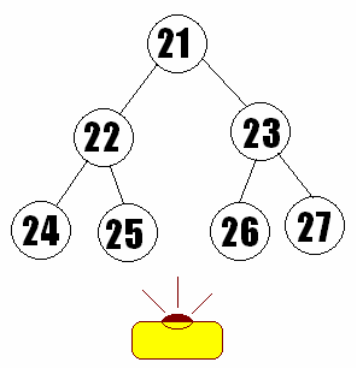

Fig. 6. The final formulation of the Heap task, that is easier understandable, it involves an interactive solution

This task was given at the Bebras Contest 2006 in all three age groups. Even the youngest pupils could solve this task due to its easy formulation using the photographer story.

To avoid use of paper and pencil in solving this task a good Bebras system should provide a possibility to interactively exchange the beavers. An automatic counter could count the number of exchanges that can be used to find the solution. In fact not all Bebras systems used by the Bebras countries in 2006 supported the interactive exchange of beavers.

7 Summary

We discussed the special challenges for the group of people who create tasks for the Bebras Contest. They have the goal to find interesting ("funny") tasks in the field of Informatics and Computer Literacy that are challenging and can be solved in a very short time. A list of criteria for good tasks helps them to create and quality check the created tasks.

In some cases a suitable story may make a presentation of a task much easier so that also younger participants may solve the problem.

We are open for all kinds of proposals and ideas of collaboration and hope to find friends and partners in all countries. Integration of information technologies into the teaching process and understanding technology while using computers should be our target. We should collaboratively try reaching it.

We are ready to share our experience, technology, and future plans with all who are interested. We expect that it will foster your own competitions similar to the Bebras contest or will encourage you to join us. We are sure that a well-organized competition with interesting, playful, exciting problems, and attractive awards will invite children of all countries to reason about proper use of computers and to explore and to understand realities, possibilities, and failings of technology.

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