Introducing informatics concepts through a contest

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Abstract
Concepts of informatics play a central role in all curricula and standards for informatics education at secondary schools. In practice at schools however very often the training of skills in application software is given much more room than the understanding of fundamental concepts of informatics. The reasons for that may be manifold: lack of time, missing teacher education, missing materials, pressure from industry, etc. In this paper, we are going to show how informatics concepts may be introduced to schools in a student-motivated and playful way. By the example of an international informatics contest we present how a contest may introduce a variety of even advanced concepts in a very short time. And about that the students need no specific pre-knowledge and learn in an explorative way to solve the given contest problems. A main focus while preparing a contest should be given to the development of good tasks that also can be used by the students and teachers in their further learning and teaching activities.

Keywords
Concepts of informatics, informatics contest, explorative learning, learning by competition

INTRODUCTION
In many countries the schools lack on good educated informatics teachers that are able to convey informatics concepts to school students in a proper way. Therefore very often the teaching of informatics concepts is at school on the decline and the use and training of application software is increasing. Furthermore concepts of informatics are often considered as too complicated to be understood by younger children. As a consequence the discipline of informatics is considered by the school students as a not very creative and innovative topic.

The international Bebras contest on informatics and computer fluency has the goal to convey informatics concepts to as many school students as possible in a way that can motivate them to be more interested in informatics. The key idea is to pose interesting problems that are from the field of informatics or can be solved with informatics methods. By solving these problems the students learn a lot about informatics concepts.

This article shows which concepts of informatics are important for schools and how the Bebras contest is able to introduce even advanced informatics concepts to young school students.

INFORMATICS CONCEPTS AND STANDARDS FOR SCHOOLS
Curricula and standards for secondary schools describe learning contents and methods of learning. In the field of informatics there were developed some international standards that define for a larger group of countries what content areas and what way of learning can be appropriate.

We discuss here the relation of curricula and standards to the concepts of informatics. In particular we address the UNESCO-IFIP curriculum, the ACM K-12 curriculum, the GI standard and the Lithuanian and the Austrian informatics curriculum.

UNESCO-IFIP Curriculum
In the UNESCO/IFIP curriculum (Anderson, Weert, 2002) the word concept is used just in the Module A1 Basic Concepts of ICT that has the objective:

> Students should be able to identify and understand the functions of the main components of a typical information and/or communication system as well as identify and understand the functions of various peripherals. They should be able to understand the main functions of the systems software environment and to utilise its features in relation to the main applications software being used.

This is a very technology based view of concepts and covers just a small part of the subject Informatics. The UNESCO/IFIP framework gives more emphasis on developing educational organizations from emerging over applying, integrating to transforming approaches than on detailing informatics concepts.

ACM K-12 Curriculum
The final report of the ACM K–12 task force curriculum committee delivered in October 2003 a model curriculum for K–12 computer science edited by Allen Tucker (Tucker, 2003). This report references the idea of IT fluency of the National Research Council and describes the IT-concepts as 10 basic ideas that underlie modern computers, networks and information (National Research Council, 1999). An IT-fluent student would master IT on three orthogonal axes: concepts, capabilities, and skills. Concepts are understood as the 10 basic ideas that underlie modern computers, networks, and information:

- computer organization
- information systems
- networks
- digital representation of information
- information organization
- modeling and abstraction
- algorithmic thinking and programming
- universality
- limitations of information technology
- societal impact of information technology

GI Standard
Interesting is also the standard developed by the German Informatics Society GI (GI, 2008). It is a proposed standard for informatics education in secondary schools grade 5 to 10. Since Germany is a federal country with 16 states that have their own school systems and curricula, there was a need for a proposal of common learning goals. The emphasis of this GI standard is on concepts of informatics and not on use of information systems (Table 1).

Content areas	Process areas
Information and data	Modelling and implementing
Algorithms	Arguing and evaluating
Languages and automata	Structuring and networking
Informatics systems	Communicating and cooperating
Informatics, man and society	Representing and interpreting

Table1: content and process areas of GI standard (GI, 2008)

Each content area can be combined with each process area. The GI standard gives in all areas examples of typical tasks that are suitable for secondary school education. The detailed competencies are presented separately for grade 5 to 7 and for grade 8 to 10. In comparing the proposed competencies and example tasks of these two age groups one can see that the same concepts can be conveyed even to younger students if the contents are presented in an age adequate form.

National standards: Lithuanian experience

The teaching of informatics has a ligneous tradition in Lithuanian schools; a rich experience in the field has been accumulated (Dagiene, Dzemyda, 2006). In 2002, the Ministry of Education and Science of Lithuania has decided to change the title of subject 'Informatics' to 'Information Technologies' (IT) in secondary schools and to teach it as a compulsory subject starting from 5 grade (age 12). Later it was decided to change scope of the curriculum and standard of teaching IT: it was shifted from basics of Informatics as science to computer literacy. Nevertheless some main concepts of informatics have been introduced mainly through optional modules.

The models of compulsory and optional courses of teaching IT in lower and upper secondary schools (grades 5-10, and grades 11-12) had been developed and revised 2002, 2003, 2005, 2007, 2010 (General Curriculum…, 2002; General Curriculum…, 2003, General Programme…, 2005). The education programme of lower secondary schools, starting with the fifth grade, includes a separate course on IT, a part of which is starting to be integrated with other subjects (mats, arts, foreign languages, etc.). Informatics concepts are expressed in introductory course of Logo in 5-6 grades (approximately 17 hours).

Grades 9–10	Basic topics / concepts
Elements of algorithms and programming	Conception of algorithms, ways of writing Programming languages, compilers Preparation of algorithms, coding and running the program Dialog between program and user Entering and output of data, printing formats Main actions of algorithms: assignment, loop Simple data types Stages of program development Control data and correctness of program Programming style and culture Simplest algorithms and their programming

Table 2: Optional IT course - programming module for 9-10 grades of Lithuanian comprehensive schools

The course on IT in grades 9-10 aims to summarize and systematize students' knowledge as well as their purposeful usage of their skills, drawing attention to the

right application of the technologies and their legitimacy. For those who wish to grasp fluency in programming principles, a 34 hours optional module on algorithms is offered (Table 2).

The IT course for upper secondary grades 11-12 is being essentially revised. Several optional modules mostly oriented to the requirements for study courses in higher educational institutions are being developed. The content of IT is directed towards the trends of information technology usage and training in this field in other European countries. Developing algorithms and programming as well as data base are optional modules.

The programming module consists of 70 hours. The teaching of programming embraces four main fields: 1) basic constructions of Pascal; 2) data structures; 3) algorithms; 4) a version of the Pascal language in a Free Pascal environment.

In Lithuanian schools, each subject's exam has its own curriculum, which is more concrete than the general subject's curriculum. The programming exam curriculum closely corresponds to the content of the module. Three main fields are emphasized: algorithms, data types and structures, and constructs of a programming language (Table 3).

Algorithms	**Data structures**	**Programming language (Pascal)**
Calculation of sums (of product, quantity, and arithmetical average). Search of the maximal (minimal) value. Data input/output. Data sorting. Ability to modify algorithms according to the particular data structures	Integer and real, char, boolean, and string Text file. One-dimensional array. Record. Ability to create uncomplicated data structures.	Program structure. Commentary. Variables Assignment and statement. Relational and logical operations, if statement Loops. Compound statement; Procedure and function. Lists of parameters and arguments. Standard mathematical procedures and functions. Procedures and functions related with files.
Programming environment. Technology of structural (procedural) programming. Testing. Program documentations. Arrangement of dialogs. Program writing (style)		

Table 3: Components of curriculum of programming exam for 11-12 grades of Lithuanian comprehensive schools

As one may notice from Lithuanian IT curriculum, the main attention is being paid to satisfy user's needs and to develop computer literacy. Teaching of the basics of informatics has become quite poor. Pupils get familiar with the basic knowledge on informatics in grade 5-6, when they have Logo course. Faintly bigger attention is being paid to developing algorithms, programming, and data base through optional modules. Therefore the Bebras contest gains bigger and bigger value in motivating pupils to understand computer and master it creatively and fluently.

National standards: teaching informatics in Austria

In Austria informatics is a mandatory subject at all grade 9 students. From grade 5 to grade 8 Informatics is a teaching principle integrated in several other subjects.

But about half of all lower secondary schools in Austria offer subjects related to ICT due to their right to offer school specific subjects.

In higher secondary schools (grade 9 to 12/13) there are in Austria two education tracks: gymnasium and higher vocational schools. Both of them end up with a graduation examination that allows starting a study at university level. The Informatics curriculum of Austria's gymnasium contains in grade 9 the following main content areas (learned in 2 hours per week):

- Problem solving strategies
- Hardware
- Software
- Outline of a problem oriented programming language
- Introduction to operating systems
- Working with application software
- Application areas of computers
- Change of life through ICT
- Privacy and data protection act
- Historic development of ICT
- New trends in technology

Emphasis is put on problem solving and a general understanding of all relevant topics of informatics. So the students usually do not learn to program in a programming language but they get a first insight. From grade 10-12 informatics is an elective subject where the students may learn some problem solving techniques like programming or use of data bases in more detail. The main content areas for grade 10 to 12 are: Problem solving through programming, first programming language, operating systems, methods of systematic problem solving, advanced word processing, selected application areas, interdisciplinary projects, second programming language, introduction to logic of electronic circuits, robotics, data bases and data representation, e-commerce, data protection act.

For all different types of Austria's higher vocational schools a competence standard for Applied Informatics was published 2009 from the Austrian ministry of education. It defines 6 content areas:

- Informatics systems
- Publication and Communication
- Spread sheets
- Data bases
- ICT, man and society
- Algorithms and data structures (for some types of schools)

and 4 levels of acting
- understand
- apply
- analyze
- develop

Practical tasks for use at school are given for each combination of content area and level of acting. As one can see from the content areas the main focus lies on proper use of informatics systems.

In Table 4 we combine the main informatics concepts for schools which were included in UNESCO/ ACM recommendations, we added some countries that have some different informatics concepts to teach at schools.

UNESCO	**ACM**	**National Curricula**
Basic Concepts of ICT Managing files Software applications Social and ethical issues Spreadsheet design Data base design Modelling and simulation Robots Elements of programming Software development Top-Down program design	Computer organization Information systems Networks Digital representation of information Information organization Modeling and abstraction Algorithmic thinking and programming Universality Limitations of information technology Societal impact of information technology	**Germany (GI):** Information and Data Algorithms Languages and automata Information systems Informatics, man and society **Austria:** Problem solving strategies Hardware Software Outline of a problem oriented programming language Introduction to operating systems Working with application software Application areas of computers Change of life throu ICT Data protection act and privacy Historic development of ICT New trends in technology **Lithuania:** Algorithms Program structure Variables Data types and structures Assignment and statement Relational and logical operations, if statement, loops, compound statement Procedure and function, parameters Recursion Control data and correctness of program Programming style and culture Commentary Algorithmic thinking Top-Down program design Societal impact of information technology

Table 4: Main informatics concepts for primary and secondary schools

BEBRAS: A CONTEST TO CONVEY INFORMATICS CONCEPTS

The Bebras contest was the first time performed in 2004 in Lithuania, therefore the Lithuanian name Bebras denoting the vivid dam building animal beaver. It is an Informatics contest for all secondary school students that is performed at school at computers and offer 18 to 24 problems to be solved by the students within about 45 minutes. There are different task sets for the age groups benjamin (grade 5-8), junior (grade 9-10) and senior (grade 11-12), in some countries there are two age

groups for the youngest: benjamin and meteor. The contestants are usually supervised by teachers who may integrate the contest in their teaching activities.

The general goals of the Bebras contest are:

- Give the students motivating impulses to be more interested in informatics
- Show the variety of informatics topics and concepts
- Show that solving informatics problems is interesting and challenging
- Give learning impulses
- Support a positive attitude to informatics

The formulation of good tasks plays an important role for the success of the contest, see (Dagiene and Futschek, 2008). In 2009 the Bebras contest was conducted in 11 countries with about 150,000 participating students. A qualitative feedback from participating teachers showed that some of the teachers wanted a testing system with better time performance but all teachers liked the quality of the posed tasks much or very much.

In (Dagiene, Futschek, 2008) we presented the following 6 task types for the Bebras contest: (1) Information comprehension, (2) Algorithmic thinking, (3) Using computer systems, (4) Structures, patterns and arrangements, (5) Puzzles, (6) Social, ethical, cultural, international, and legal issues. The descriptions of these task types involve also concepts of informatics although this was not the goal of this classification. It gives anyway a rough idea what kinds of problems and what topics of computer science we have in mind for the Bebras contest. In short, Bebras tasks can involve concepts of informatics like algorithms and programs: sequential and concurrent; data structures like heaps, stacks and queues; modelling of states, control flow and data flow; human-computer interaction; graphics; etc.

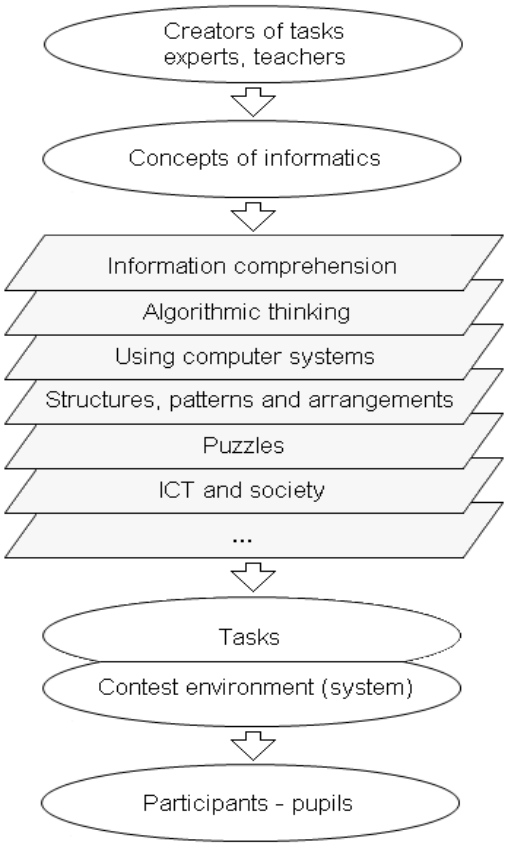


Figure 1: Overall structure of the Bebras contest

In the short text of the Bebras tasks we can involve concepts of informatics like algorithms and programs: sequential and concurrent; data structures like heaps, stacks and queues; modelling of states, control flow and data flow; human-computer interaction; graphics; etc. Using a proper problem statement nearly all aspects of computer science and ICT can be topic of a Bebras task, see also (Futschek and Dagiene, 2009).

WHAT INFORMATICS CONCEPTS DO WE NEED AT SCHOOL?

What informatics concepts should be included in school curricula? Only few authors started to discuss this topic, e.g. (Hromkovic, 2006). Hromkovic suggested the inclusion of three main topics: programming, algorithm complexity, and theory of automata.

Teaching informatics started with programming. Sometimes it was interpreted that machines at that time were miserable and that programming was the exceptional possibility to manage them. However, the goal of teaching programming is problem solving transfer, i.e., users are expected to be able to apply what they have learned to solving problems that they have not been taught (Mayer, 1991). Furthermore, programming is the best way to build a language for instructing (communicating) a machine. According to Hromkovic “We have to teach programming as a skill to describe possibly complex behaviors by a sequence of clear, simple instructions“ (Hromkovic, p. 33). Later, Avi Cohen and Bruria Haberman went further and declared computer science as a language of technology (Cohen, 2007).

What is informatics, or computer science, or computing? We can find a lot of definitions for informatics. UNESCO has defined one of the most general (Anderson, Weert, 2002):

> Informatics is the science dealing with the design, realization, evaluation, use and maintenance of information processing systems, including hardware, software, organizational and human aspects, and the industrial, commercial, governmental and politician implications of these.

In the same document UNESCO presents a definition of ICT:

> Information and communication technology, or ICT, is defined as the combination of informatics technology with other, related technologies, specifically communication technology.

Information and algorithms (programs, computers) and computational processes are the main objects of informatics. From here we can retrieve the very general main informatics concepts: algorithms, programs, information, information systems, methods of representation, processing, storage, transmission information, etc.

The hardest question is to agree which informatics concepts are necessary to bring to school (after that we will have very hard question how to teach them, etc.). Juraj Hromkovic discussed what to teach in informatics at school and made proposal: to start with programming and combine with algorithms, then teaching fundaments of informatics should include automata theory (the reason is that finite automata provide the simplest model of computation) and the last part can be devoted to computability (Hromkovic, 2006).

It has been generally agreed on teaching some groups of informatics concepts in a comprehensive secondary school. For example, there is no doubt that algorithms,

programming are among the most important concepts of informatics. The algorithm concept could be decomposed into smaller components as well into rather important partial concepts, e.g, data, variables, loops, procedures, objects, classes. Structures and patterns are also significant concepts for schools. There are no doubts in to the belonging of the information concept to informatics and IT.

It is difficult to characterize computer systems. Even the title of the concept outlines IT application rather than a theoretical basis. If a concept is not quite pure and clear, there arises difficulties to use it, over more to teach it (as usual, there is a gross deviation to applied aspects). Also not quite clear are the social aspects of technology – we can hardly state that it is a concept of Informatics. There are no doubts that social aspects are important and indispensable in the contemporary society, however, there is often a lack of systematization and teaching examples for this topic.

Puzzles are treated as a contest element rather than a concept of Informatics or IT. However, puzzles and games incorporate some attractiveness to any contest and increase motivation of students. It is possible (and it should be) to express the concepts of scientific areas by puzzles.

In case one succeeded to find an adequate answer to the question what makes the basis of Informatics and IT as sciences, it would be easier to perform the taxonomy of concepts and to prepare the necessary concepts for learning Informatics at school. Then it is likely to succeed in providing a modern framework of Informatics and IT curricula.

The main concepts of Informatics and IT necessary for students have been discussed in recent years. In Lithuania, they are partly defined in general curricula and standards of general education. In this aspect we shall discuss the results of recent Bebras contests.

When preparing the contests we try to select tasks for the age groups so that they would reflect the concepts of all the six domains. As seen in Figure 2, the distribution of task types is not uniform, but this was not the aim: not each group of concepts in equally important, algorithmic thinking, information and structures are of importance for school training in Informatics. It is desirable to keep the proportionality among the age groups. While modelling concept groups in the first years of contests (2004-2006), there was a big imbalance.

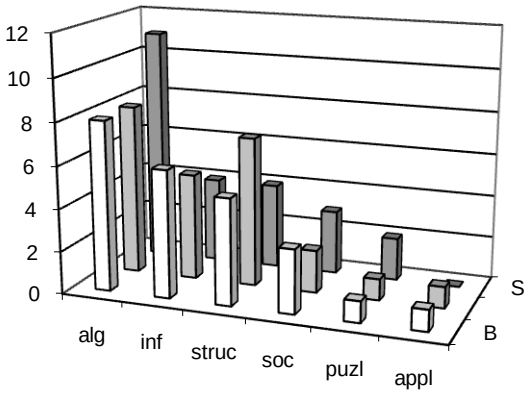


Figure 2: Distribution of tasks in the age groups (Benjamins, Juniors, Seniors) according to the 6 concepts of Informatics and IT in Lithuania in 2009

Recently the distribution of tasks has become more uniform, the concepts are reflected by the problem sets. In Lithuania' Bebras contest 2009, there were no tasks of computer use for grades 11-12, however, on the other hand, they had more tasks in the field of social issues, which is more important for senior students. In general, more attention should be paid to the issues of social and ethical issues at schools, therefore more tasks in this field are desirable to submit.

It is of importance for Informatics educators and teachers to find out how the students succeeded in solving the problems and to understand thereby the concepts of Informatics and IT. By the analysis of the contest data 2009, we have noticed that the participants had some difficulty to defeat the algorithmic and information comprehension tasks while they could easily manage the applied problems (Figure 3). Differences between the age groups were not so large, except the groups of pure social matters, - the problems for senior students were too easy.

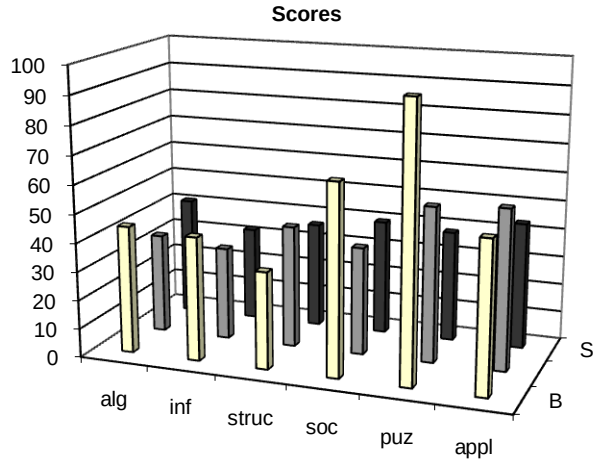


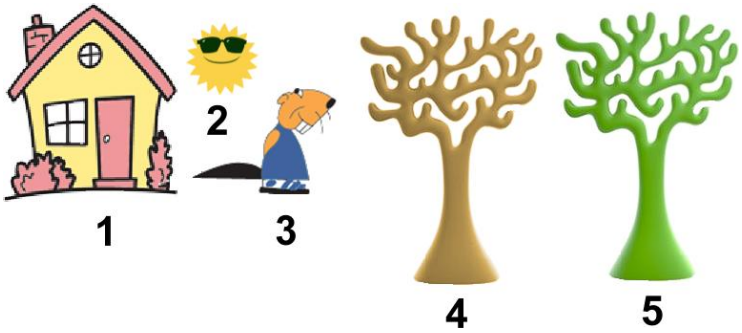
Figure 3: Distribution of task solutions according to concepts and age groups in the contest of 2009

Another recent analysis of the results of the Bebras contest from I. Kalas and M. Tomcsanyiova (2009) shows that there are no significant differences of the results of girls and boys.

EXAMPLE BEBRAS TASKS

We present here typical Bebras tasks and discuss the concepts that may be learned by these tasks. It is also interesting to point out that these tasks illustrate that we do not ask for already learned knowledge. We want to let the students discover the informatics concepts by well chosen tasks. To solve the tasks the students have to explore the stated problem domain and have to work with data, structures, activities and problems which are typical for informatics. Usually there are many different ways for finding a solution. So the contest also supports students that prefer different types of solution strategies.

Mandatory Benjamin task: stamping (created by Lithuania)
Beaver has five stamps and they are numbered from 1 to 5:



He stamped a nice picture:

In which order did beaver use the stamps?

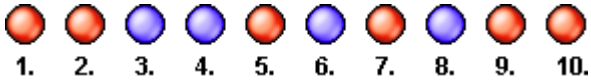
A) 5 - 2 - 4 - 3 - 1
B) 5 - 3 - 4 - 2 - 1
C) 5 - 2 - 3 - 4 - 1
D) 5 - 4 - 2 - 3 - 1

While solving this task even the younger children learn a lot about concepts of programming: coding of basic actions as commands (1 to 5), sequencing of commands and even reverse engineering! Although there is not a concrete algorithm part of this task this task can be classified as algorithmic thinking task. As shown in figure 2, this mandatory task was an easy to solve task for the Benjamin age group.

Sample task: red and blue beads (created by Slovakia)
In ten small holes in a row there are ten beads which colour can be either red or blue. Each bead is put in one hole. The holes are numbered 1 to 10.

There is a robot, which can sort the beads so that red beads should be in the first holes from the left and blue beads should be in first holes from the right.
In one step the robot exchanges two beads.

The robot has started in this position:



What is the minimum number of steps to sort the beads properly?

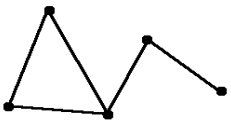
This is an interactive task from algorithms concepts group. It is surprising that in Lithuania 99.33% of Juniors submitted right solutions and there was no difference between girls and boys! Approximately solving time - 1 min 52 s.

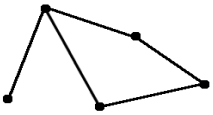
Sample task: friends (created by Estonia)
We know that

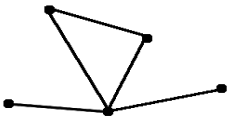
- Michael's friends are John, Peter and Tom
- John's friends are Michael and Anne
- Anne's friend is John
- Peter's friends are Michael and Tom
- Tom's friends are Michael and Peter

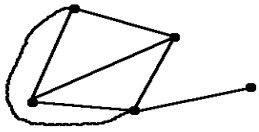
We represent people as points and we draw a line between two people if we know that they are friends with each other.

Which of the given figures can be obtained this way?

a. 

b. 

c. 

d. 

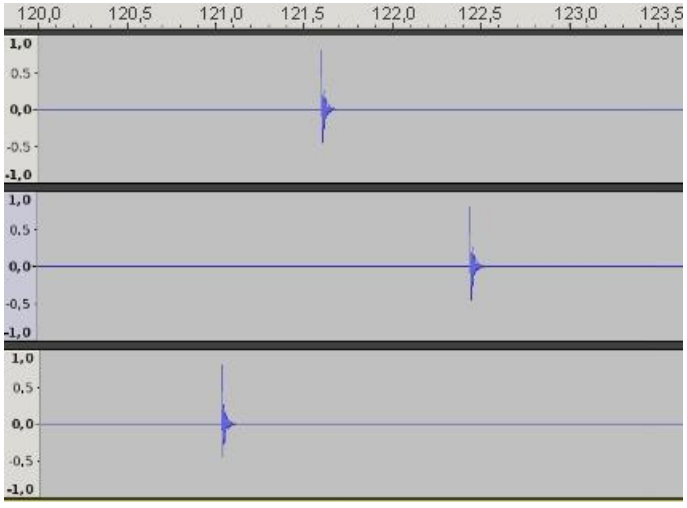
This was in the Bebras 2009 contest a mandatory task for elder Benjamins. It is a task of type structures that allows learning experiences in representing relations by graphs. So the concept of a graph is learned while solving this task.

Sample task: acoustic intelligence (created by Estonia)
There are three microphones on the ground (see picture). At some moment a dog barks once. All three microphones detect the sound as shown on the graphs.

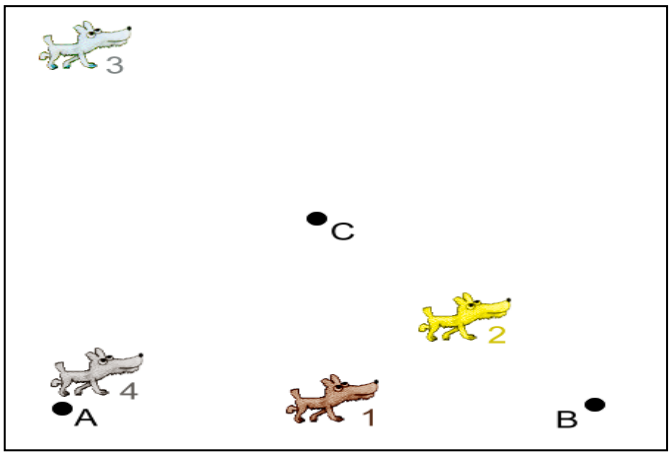
Microphone A

Microphone B

Microphone C

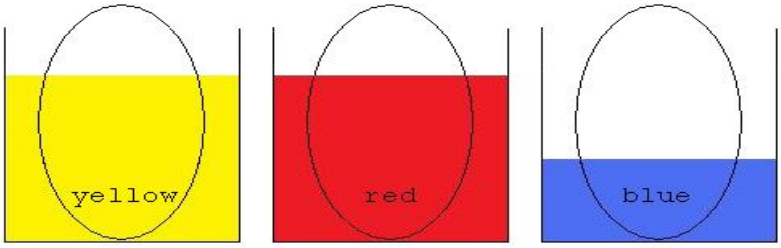


Which of the four dogs on the picture has barked? The black dots mark the microphones.



To solve this task one has to understand that barking takes time to reach a microphone, so the distance of the barking dog to the microphones results in different times the graphs indicate the barking signal. In solving this task the students learn a lot about the concept of information representation.

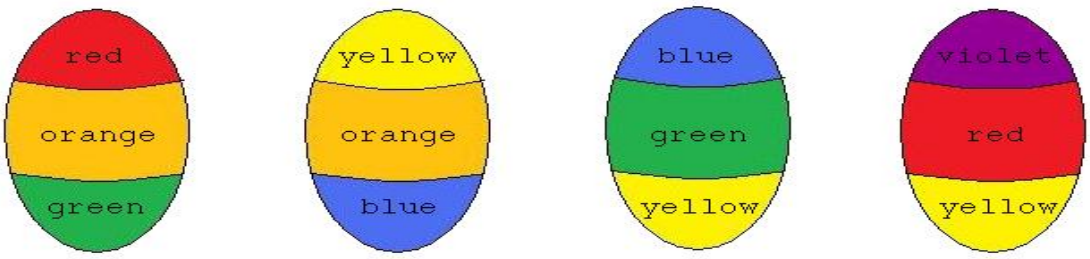
Mandatory task for all age groups: rainbow eggs (created by Germany)



Lina dyes eggs. She uses three cups of colour. There is plenty of yellow and red colour, so she can dip two thirds of each egg into yellow or red. But there is little blue color, so she can dip only one third of each egg into blue. Lina dips all eggs as deep as possible:

- Yellow and red mix to orange.
- Yellow and blue mix to green.
- Red and blue mix to violet.

Lina never mixes more than two colours. For example: By dipping one egg into red, then into blue, then turning it over and dipping it into blue again, she gets an egg that is violet-red-blue.



Only one of these eggs could have been dyed by Lina. Which one?

a) red-orange-green b) yellow-orange-blue c) blue-green-yellow d) violet-red-yellow

This task was selected in Bebras Contest 2009 as a mandatory task for all age groups. Maybe it is not immediately obvious what informatics concept is supported

by solving this task. But to solve this task correctly one has to find the correct order of well defined basic colouring operations and has to imagine the effect of these operations. One has to reverse engineer from the given result to the correct sequence of operations. The same way of thinking is necessary in computer programming.

CONCLUSIONS

In comparison of the Informatics standards and curricula at school we found out that there are just little coincidences. Even the key competences algorithms and programming are not part of all curricula. It seems to be necessary to provide the community with a new actual standard that incorporates also actual developments in communication technologies and cooperative work.

Aspects of all school relevant informatics concepts can be part of contest problems. Especially for younger contestants it is necessary to formulate the tasks in an adequate way. The pupils learn aspects of the involved concepts by exploring the problem and by finding suitable solutions.

To find out how much a contest contributes to learning success, motivation, attitude towards informatics, etc. should be topic of a future investigation.

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