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# Bebras – a Sustainable Community Building Model for the Concept Based Learning of Informatics and Computational Thinking

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**Abstract.** As an international informatics contest, or challenge, Bebras has started the second decade of its existence. The contest attracts more and more countries every year, recently there have been over 40 participating countries. From a single contest-focused annual event Bebras developed to a multifunctional challenge and an activities-based educational community building model. This paper aims to introduce the Bebras model using ten years of observations in implementing the contest in different countries. The model is essentially based on democratic and inclusive education values. Systematic literature review of research papers concerning Bebras activities has made an integral background for this model. The model is represented both at international and national levels and consists of several components where the development of Bebras tasks has taken a very significant role. Reasoning on innovated learning informatics and strengthening computational thinking by utilising carefully selected informatics concepts is discussed as well.

**Keywords:** Bebras challenge, computational thinking, contest, democratic education, informatics concepts, informatics education, systematic literature review.

## 1. Introduction

Attracting youngsters to choose to study computer science or informatics – an equivalent terminology often used within Europe – at schools has always been a challenge for educators. The idea of developing contest on informatics fundamentals for school students was raised by Lithuania in 2004 (Dagienė, 2005; 2006). Recently, the contest has been spreading over 40 countries involving various activities, e.g. several rounds of the contest, discussion on informatics topics, task solving seminars, teacher workshops, and task developing events. Since 2015, Bebras contest on informatics and

computer fluency was renamed to Bebras challenge on informatics and computational thinking (bebras.org).

The contest name "bebras" is a Lithuanian word for "beaver" and it was chosen in connection with the hard-working, intelligent, goal seeking and lively animal. Some countries use the "bebras" for their national contest (for example, Azerbaijan, Iran, Ireland, Italy, Japan, Spain, Taiwan, USA), and some countries translated it to their languages (Estonia – kobras, Finland – majava, France – castor, Germany – biber, Serbia – dabar, Slovakia – bobr, UK –beaver, etc.).

The main goal of the Bebras challenge is to motivate pupils to be interested in informatics topics and to promote thinking which is algorithmic, logical, operational, and based on informatics fundamentals. The Bebras activities have to promote pupils' interest in informatics (also in information technology) at the early stage of the school education and to motivate pupils to learn deeper and master better technology (Dagienė, Futschek, 2008). Specifically, the idea is to encourage children to learn informatics fundamentals (concepts), and to support development of algorithmic thinking as well as computational thinking.

Our aspiration is to wrap up serious scientific problems of informatics and the basic concepts into playful tasks, inventive questions thus attracting students' attention. It is not an easy matter to prepare tasks in such a way. Representatives of the Bebras countries create and offer the assignments whole year long, and in spring they come together to discuss and choose the most suitable ones for the contest in autumn.

Development of the Bebras tasks assignments is even more difficult concerning the fact that teaching of informatics is very different at schools in different countries. Naturally informatics is too young discipline to have adopted common agreements and clearly crystallised topics in different countries. We, the scientists of informatics, have to discuss, consult and find common practices and conventions.

Thus, one of the most serious desires of Bebras is to find a place for informatics at schools, to reach an agreement on the principal topics and notions. Therefore, we are pleased to have succeeded in uniting a team of enthusiastic education scientists and experts who are interested in informatics science.

The Bebras challenge has been developed for all primary and secondary school pupils. The contest is meant to be performed in schools at computers. Pupils should solve 18 to 24 tasks within 45 to 55 minutes. There are different task sets for the age groups:

- Little Beavers (grades 3–4).
- Benjamin (grades 5–6).
- Cadet (grades 7–8).
- Junior (grades 9–10).
- Senior (grades 11–12).

The participants are usually supervised by teachers who may integrate the contest in their teaching activities.

In the past few years, the number of the Bebras participants has been notably growing. It outreached 1.3 million of pupils during contest in autumn 2015.

## 2. Bebras – an Inclusive Education Model for Learning Informatics Together

The Bebras challenge is an education community network which consolidates over 40 countries to discuss together informatics concepts for school informatics education. The Bebras task developing workshops organised annually (since 2005) bring together the representatives of all these countries for hard work and making decisions on good tasks for promoting informatics education at primary and secondary schools.

From one side, the Bebras challenge is an international assembly driven by informatics education needs over the world. From the other side, almost all activities are based nationally, organised by country communities. Working together more than a decade, we have discovered principles of a democratic and inclusive education and a huge potential of creativity within the Bebras community.

As many education theorists have agreed, a democratic education is an educational ideal in which democracy is both a goal and a method of instruction. It brings democratic values to education and can include self-determination within a community of equals, as well as such values as justice, respect and trust. Democratic education sees young people not as passive recipients of knowledge, but rather as active co-creators of their own learning. They are not the products of an education system, but rather valued participants in a vibrant learning community (Caine, 2009).

The main ideas of the democratic education are discussed in a Waghit's book (2014). Drawing on the works of poststructuralist theorists, Waghit argued that a democratic education in becoming has the potential to rupture pedagogical encounters towards new beginnings on the basis that teachers and students can never know with certainty and completeness. In democratic education, students and teachers are provoked to contribute to the community building and enhance their young citizens 21st century skills.

Consequently, many educators argued that teaching and learning in the democratic education ought to be associated with pedagogical activities in the making and solving everyday life tasks. We would like to add more concerning tasks: the tasks should be interesting for children, related to their activities, containing science (e.g. informatics) concepts, fun, etc. Additionally, we would like to extend democratic education to a mixed model of informal societies (e.g. the Bebras community) or groups of people with common interests to learn and gain some specific competencies.

Observing ten years' developments of the Bebras contests and activities, we elaborated a Bebras challenge model based on democratic education ideas and constructionism principles. Constructionism, as a learning approach (Ignatova, Dagienė, Kubilinskienė, 2015), is mostly applied to the development of tasks and task solving activities for students as well as teachers. The model combines both international and national levels and involves variety of activities especially at country level (Fig. 1).

Management of the Bebras challenge consists of three main bodies at national and international levels: National Bebras Organisation (NBO), International Bebras Community (IBC) and the Bebras Board (BB).

The National Bebras Organisation is responsible for many activities within a country and all year round: creating and submitting new tasks, reviewing tasks, participating in Bebras task evaluation workshops, selecting and translating tasks, organising challenge,

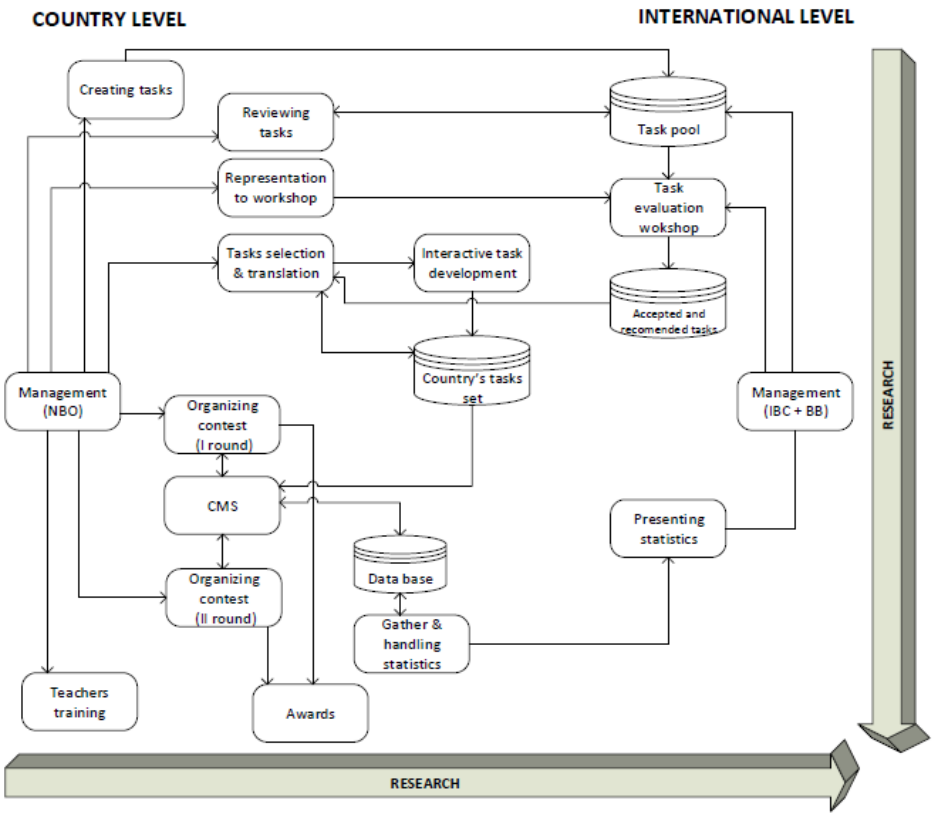


Fig. 1. The Bebras challenge model.

producing teaching material and Bebras task brochures, training teachers. There may be only one NBO per country.

The International Bebras Committee is composed of NBO representatives. During the annual meeting, the international Bebras workshop, all NBO delegates are considered IBC members. For all IBC actions to be taken in between the workshops, each NBO nominates one representative as a voting member of the IBC.

The Bebras Board is the executive body of the Bebras community and is responsible for all ongoing business of the community. The main functions are to take care of tasks (to develop new categories or patterns, new tools, etc.), especially to support the Bebras task evaluation workshop, and provide feedback to the community.

The members of the Bebras community are organisations responsible for organising a national Bebras challenge in their country.

The model has time constraints: some activities are strongly restricted by time limits (in months). For example, an annual task evaluation workshop should be organised at the end of May, so two months before, the preparation of high quality tasks should start. Following that, all new tasks should be delivered until the end of March – task reviewing process is taking place then. Each participating country should provide from 5 to 10

tasks. Anybody of the Bebras community may act as a reviewer. At least 2 reviewers are assigned for each proposed task.

After tasks reviewing process finishes, discussions on accepted and recommended tasks begins. Usually it takes place during the first and second days of the international task evaluation workshop.

The NBO must select and translate tasks for the annual Bebras contest. The second full week of November is considered as an official time for the Bebras challenge (first round) in participating country and named by International Bebras Week (for countries in the southern hemisphere, a different week may be chosen) (Bebras Community Statutes, 2015).

Several countries have established a second round of the Bebras challenge, usually at the end of January or beginning of February, and it is dedicated for the best participants of the first round challenge. Usually, the first and second rounds are followed by different coming together meetings and awards for the best students.

Teacher training is one of very important activities of local Bebras communities. Countries are continually working on developing modern approaches for informatics teacher training, producing learning materials, organising hands-on seminars, etc. (Schulte *et al.*, 2012). Thousands of students are involved in solving the Bebras tasks. It is a good possibility to collect enormous amounts of data on student performance and investigate them.

Tasks are the most important and exceptional part of the Bebras model. The quality of tasks is crucial for the success of a contest. Usually, contests have several goals and the tasks have to fulfil a wide variety of criteria (Hakulinen, 2011). 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, contests are one of the best ways to capture their attention (Dagienė, 2008). In educational contests, tasks should attract students and drive them to learn and explore as well to develop skills in the particular area.

Bebras tasks are short, answerable in a few minutes through a computerised interface, and requiring deep-thinking skills in the informatics field. The tasks should be answered without prior knowledge in informatics, and they are clearly related to fundamental informatics concepts. To solve those tasks, pupils are required to think in and about information, discrete structures, computation, data processing, data visualisation, and they should use algorithmic as well as programming concepts. Each Bebras task can both demonstrate an aspect of informatics and test the participant's ability of understanding informatics fundamentals (Dagienė *et al.*, 2015).

Each year the international Bebras task evaluation workshop confirms a set of new tasks and questions. International experts in informatics follow 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 fulfil all criteria. Often it is a process of several versions from an imperfect task formulation to an acceptable formulation. The main criteria for tasks 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 independent from specific systems.

The easy understandability of tasks is in all contexts a very important goal. It is not only the wording but also the presentation of the task that may include interactive elements. 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. Tasks should also be funny and should have interactive elements.

The interactivity is very typically 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. However, the interactive elements are time consuming especially while implementing tasks in different systems. Anyway, due to the attractiveness of interactive tasks, the high effort for implementing the interactive part is worth to be done.

## 3. Literature Analysis

Inquiring data and improving technology for running the contest or developing tasks are questions that many countries are started to look at. Many research works are done. For better understanding in which direction the research concerning the Bebras challenge is going, we decided to make revision of research publications by using a systematic literature review (EPPI-Centre, 2007).

*Sources*: Web of Science, ACM Digital Library, Springer Link, SCOPUS, Google Scholar. *Search term*: Beaver contest OR Bebras contest OR Bebras challenge. *Language*: English. There was no time limitation for publication. The Bebras was establish in 2004, and the first publication appeared in 2005 (Fig. 2).

149 papers on informatics Bebras were found, but only 76 met the language criteria. The remaining 73 papers were published in different languages (Czech, Finnish, French, German, Italian, Japanese, Lithuanian, Russian, Slovakian, Slovenian, and Mandarin Chinese).

In this analysis, the selected 76 papers are used. The papers are divided into three categories:

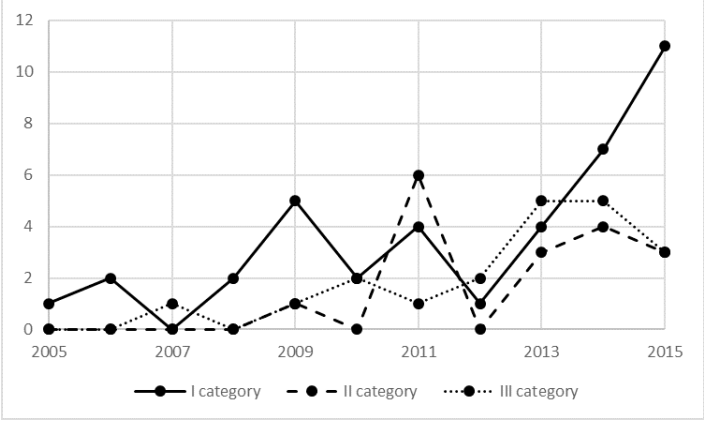


Fig. 2. Number of papers by years and categories.

1. Bebras contest is the main source for research questions (39 papers).
2. Bebras contest is discussed as a good practice for informatics education (17 papers).
3. Bebras contest is only mentioned between the other activities (20 papers).

Number of research papers is significantly growing during the last years (Fig. 2).

At first, all the 76 papers were analysed by their keywords in order to find out the key topics of the Bebras challenge. Naturally informatics education, computer science, programming, contest, learning, computational thinking and problem solving are the most dominating topics (Fig. 3).

Further we are going to analyse 56 papers where the Bebras challenge is the main source for research questions or reasoning of good informatics education practices.

The review was driven by the following research questions:

1. What evidence in the literature is there to identify that the Bebras contest is effective enough in promoting informatics concepts and computational thinking in children and young people?
2. What evidence in the literature is there how to develop the quality of the Bebras contest?
3. What evidence in the literature is there to see the impact of the Bebras contest for formal and/or informal informatics education in countries?

One of the first papers was aimed to introduce the Bebras contest idea (Dagienė, 2005). The main message for readers was to propose that competitions can play an important role as a source of inspiration and innovation. A contest may be a key to create new knowledge and become an attractive way to bind up technology and education. There was an invitation for informatics enthusiasts and everyone who are interested in informatics education for schools to think about the proposed Bebras idea, to investigate the local situation and to join the initiative.

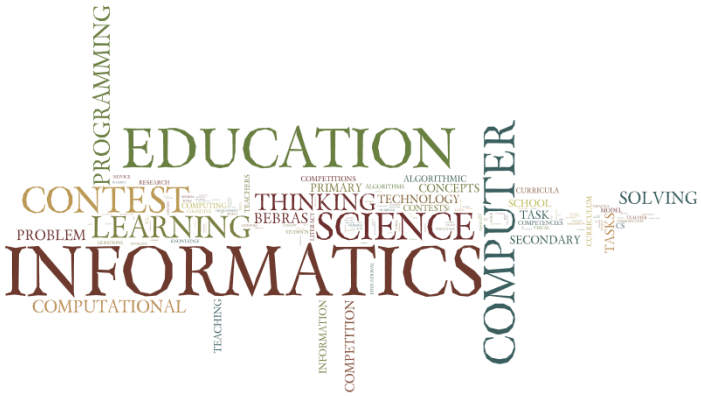


Fig. 3. Cloud of papers' keywords.

### 3.1. *The Bebras Contest is Effective Enough in Promoting Informatics Concepts and Computational Thinking in Children and Young People*

One of the most important objectives of the Bebras challenge is to support deeper understanding of informatics rather than reproduction of previously learned facts. In 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 and graphics (Futschek and Dagienė, 2009). Creative and interesting tasks are the main driver for the Bebras contests. Understanding and handling the basics and foundations of informatics is more important than knowing a lot of technical details. This contest is informal learning-by-doing while solving attractive and challenging tasks (Haberman *et al.*, 2011)

Relevant aspects of informatics concepts to all schools can be part of the challenge problems. Especially for younger contestants, it is necessary to formulate the tasks in an adequate way. A contest may introduce a variety of even advanced concepts in a very short time. The 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 (Dagienė and Futschek, 2010). Teachers should learn how to explain what is behind one or another Bebras task. We found that the Bebras tasks are well-balanced according to the cognitive skills' domains (Bloom taxonomy): at the most tasks are in the high categories Understanding, Applying, Analysing and Evaluating (Dagienė and Stupurienė, 2014).

The common practice for the contest is to include a larger proportion of tasks related to algorithms and programming concepts. The average ability to solve a certain task is largely independent of the school system. Students seem to struggle with abstract thinking (Dagienė *et al.*, 2014a).

Initially, the Bebras contest was dedicated to introduce both informatics and information technology. Later, starting from 2011, the Bebras contest became a complex approach for deeper learning informatics and developing a computational thinking. The research area was expanded and more articles were appearing in the informatics education research community.

In the context of primary school, Bebras tasks can be used with a focus on programming (Gujberova and Kalaš, 2013). It is needed to understand what cognitive demands pose these tasks to primary school pupils, what the pupils consider difficult and what they consider easy. These questions could help all of us in searching the better pedagogy for the primary programming education. It is important to emphasis on developing computational thinking, programming, designing computational systems and other basic concepts of informatics.

To master complex education scenarios, e.g. learning algorithms, data structures, programming or data modelling, the educational technique of "didactic reduction" is very useful. For getting better educational results at the end, the teacher may reduce details in the learning contents at the beginning. The goal of learning computational thinking is to understand principles and concepts in informatics. Some Bebras tasks are

used as examples of learning scenarios with different forms of extreme didactic reduction (Futschek, 2013).

The promoting idea of the Bebras contest is not to test students' knowledge, but in long time period, it looks like that this contest can be used for assessment. Authors investigated the "task based assessment" approach of the international Bebras contest by classifying (according to computational thinking categories) the conceptual content and question structure of the Bebras tasks during the years 2010–2014 (Barendsen *et al.*, 2015). In the Bebras tasks, algorithms and data representation were found to be the main concept categories (for the K-9 education). There was constructed a classification for question types (only for algorithms categories). Among the algorithms-related tasks, verification questions were the most common in all years except 2014. It makes some sense that verification questions are popular for a contest structured around multiple-choice questions. The predominant presence of algorithmic aspects in Bebras tasks might make this "task based assessment" interesting for K-9 teachers.

Computational thinking is presented as one of the main strands of CSTA K-12 Standards (Seehorn, 2011). One of the most important required cognitive operation, (mentioned in this CSTA document) is: use visual representations of problem states, structures, and data. This might inspire the Bebras community to develop tests for computational thinking based on the Bebras questions. For this purpose, after a thorough analysis of the questions of all contests up to now, some suitable sets could be assembled to form test booklets that indeed could measure the computational thinking standards of the CSTA (Hubwieser and Mühling, 2015).

Bebras tasks could be used to a wider community than it is planned, not only for school students. Research done by Dolgopolovas *et al.* (2015) aimed to evaluate novice college students in Software Engineering. The first step of the research process was developed as a homogenous dichotomous test using the Bebras contest tasks as the test questions. By solving the presented tasks, students needed to employ their computational thinking skills, which the research team intended to measure as a latent trait. Ten computational thinking tasks were selected and the average results of the solving these tasks were 54.2%. The next steps of the test process included questions requiring students to identify informatics concepts which were presented in the first step test tasks. The type of activity of the students during this study (game-like informatics task with the concepts "encoded" into it) was not only to test students but may be useful as a learning activity for informatics/engineering students. The activity itself may be highly motivational to learn new informatics concepts.

In psychometrics, item response theory (IRT) is a paradigm for the design, analysis, and scoring of tests, questionnaires, and similar instruments measuring abilities, attitudes, or other variables. Sets of the Bebras tasks represent a psychometric test that measures certain joint psychometric constructs (and competencies). While the results are promising for the Bebras challenge, the main goal was to propose a methodology in the form of a specific process of evaluation and a proof of concept for this. The results show that this methodology works and might result one day in a set of empirically founded competencies in the field of CT (Hubwieser and Mühling, 2014a). Similarly, to PISA, the tasks are proposed by the members of an international board of experts. First, it is

necessary to stress that the Bebras contest is not a PISA like study. This might be the most probable reason for the low number of question combinations that are measure some homogenous psychometric constructs in a suitable way. Additionally, the Bebras contest does (at least officially) not require any pre-requisite knowledge (Hubwieser and Mühling, 2014b; Hubwieser and Mühling, 2015).

### 3.2. *How to Develop the Quality of the Bebras Contest?*

There are many quality aspects in the Bebras challenge: first, tasks (developing criteria for good tasks, visualisation, correctness, etc.), second, online contest management systems (effective, user friendly, flexible), third, importance of learning (informatics concepts), etc.

Task categorisation and classification is one of the early research questions. The proposed topics are of the following major groups (Opmanis *et al.*, 2006):

1) General logic.
2) ICT in everyday life.
3) Practical and technical issues.
4) Information comprehension.
5) Algorithms and programming.
6) Mathematics underlying informatics.
7) History and trivia.

Later (in 2008) the Bebras tasks' categories were revised, and a modified classification came out (Dagienė and Futschek, 2008):

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.

This classification is used until now, though it has a lot of critics and limitations that are more and more visible. This category system has shown to be too coarse to be useful for task set assessment. In order to develop a fine-grained classification, a more complex system is needed to combine the following aspects (Pohl and Westmeyer, 2015):

(1) The computational thinking vocabulary lists.
(2) The fundamental ideas of informatics are based on three "master ideas": algorithmisation, structured dissection, and language (later extended to formalisation).
(3) Areas of "content competences" used to define educational standards for informatics education in middle school: information and data; algorithms; languages and automata; informatics systems; and informatics, man, and society.

Kalaš and Tomcsányiová proposed different categorisation of the Bebras tasks in 2009. They developed four components of informatics education and suggested to use

them for categorising tasks: digital literacy; programming; problem solving; and data handling (Kalaš and Tomcsányiová, 2009).

Contests can be a form of learning and a way to test children's (age 8–9) knowledge (Tomcsányiová and Tomcsányi, 2011). Children have digital skills, but it is important to prepare the tasks for them in very special way. Pupils of these ages read more slowly and do not always understand the text correctly; children at this age need to work with concrete objects within the software and they do not understand abstraction; children at this age cannot focus on a task for a long time.

There is coherence between the assignment of tasks and the errors students make (Hansky *et al.*, 2011). A general classification scheme of typical error types developed by Weimer (psychology) was the basis of the study. Since the proposed categories did not cover all errors that were identified during the analysis, the authors suggested to extend the categorisation with the error types mistake, error of false conclusion and strategy error. Based on the commonalities of tasks, it can be concluded that mistakes occurred if the task setting was closely related to the world of experience, and if it activated the cognitive process level memory. The introducing information should be provided more than once, e. g., as text plus diagram. Errors of false conclusion appeared together with the requirement of conceptual knowledge. The less the students know about concepts, the more likely are these errors. Therefore, there should be more training in the area of concepts.

It is equally important to pay attention to formulation (text phrases) of the incorrect answers in multiple-choice tasks as their quality may considerably influence task difficulty – this was the main result and message of the research paper published by Vaníček (2014).

Tasks are the keystones of the Bebras challenge. Some researchers have focused on phenomena that are directly related to informatics concepts (e.g., algorithms, data structures). One of the interesting objectives was to categorise the pictures of Bebras tasks according to their function, content and type. When categorising pictures according to their content, Tomcsányiová and Kabátová (2013) proposed three categories (problem setup pictures, pictures depicting an informatics concept, and pictures showing a user application interface) covering the majority of task pictures. Understanding and interpreting diagrams are at the core of solving process, whatever the answer requires a direct manipulation or mental process. In this sense, the Bebras tasks are "situational images".

Many of the Bebras tasks have diagrams or schemas to visualise the content of a question. A majority of diagrams are schematic and give an abstract representation of the problem to be solved. Most of those schematic diagrams are conventional representations used in informatics: graph, tree, grid and also diagrams showing processes or structural relationship between objects. Another frequent type of diagrams is icon and drawing. Icons represent objects and highlight on some of their properties by using a visual code for properties values (Tort and Drot-Delange, 2015). It is important to enable blind pupils to participate in the Bebras contest as well. The results achieved by blind pupils and factors affecting these participants as well as suggested rules of adaptations were analysed in one of surveys (Jašková and Kováčová, 2015).

In order to improve the quality of tasks, developers should use short sentences; words or phrases repeatedly; clear definitions; a one-to-one relationship between words and objects; appropriate analogies; and unambiguous wording (Pohl and Hein, 2015). Interactivity of tasks makes the contest more attractive if interactivity means manipulation with mouse. If tasks stem out from real life situations, it will be appreciated by older contestants. Younger will enjoy motivation through the fairy tale character of Beaver (Vaníček, 2014). Another aspect is guessing – students merely choosing an answer at random instead of leaving it blank. A guess is frequent in multiple-choice questions: about 10% of contestants try to guess the right answer and boys do it more frequently (Dagienė *et al.*, 2014a; Dagienė *et al.*, 2015).

Pupils are more disposed to solve tasks (or guess the answer) than to make "no answer" choice. The simplest (tasks of low difficulty and complexity) are those called in competition slang "consolation tasks". Their solution is possible for practically each participant. The existence of such tasks in competition gives a positive emotion even to those who solved few tasks only. Researchers have noticed that the number of such tasks proposed for competition was negligible (Yagunova *et al.*, 2015).

Case study from Turkey (Kalelioğlu *et al.*, 2015) was based on school student performance. Students were successful with an average score of 65.01 (scores varied between 0 and 135). Results can be regarded as successful because of the quality and level of difficulty of the questions, as well as the requirements for algorithmic skills to solve them.

Other case study from Czech Republic and Slovakia (Tomcsányi and Vaníček, 2009) introduces the contest and compares the situation from the point of view of motivation, organisation, publicity, realisation, and number and structure of participating students in these two countries.

Statistical data from Germany (Schlueter and Brinda, 2009) was used in the study directed to modelling the competence requirements of tasks in informatics. Initially, the focus was on the relevance of a catalogue of criteria affecting the task difficulty where relevance is supposed to mean the practicability as well as the interrelation between criteria and competence requirements.

Since pretesting is impossible, it is useful to find out what kinds of tasks were misplaced and develop some guidelines for predicting the difficulty level. Vegt (2013) proposed the use of a questionnaire that can be used to discover probable causes of difficulty. The answers can be used to compare questions and to discuss the estimation of the difficulty level of the question.

The same problem with difficulty level is mentioned in research where authors found that a priori evaluation of problems by the organisers does not correspond to the difficulty of the task experienced by the participants (Yagunova *et al.*, 2015). The researchers underestimated the complexity for younger pupils and overestimated the difficulty for older. The pupils, especially primary school kids, frequently underestimate the complexity of the tasks. Researchers suppose that the task length was the factor which determined a large number of refusals in junior classes, even though the tasks were not complex, in fact. Another complicating factor is interface peculiarities of a competition. Tasks containing long texts may have not enough space to be presented on one screen. For senior students, the length of text is not an extra complicating factor. Having made mistake

with assessment of task difficulty for junior schoolchildren, the experts evaluated best of all the complexity of tasks for them. That is to say, the experts do not evaluate accurately the difficulty of tasks for juniors and their complexity for seniors.

Bloom's taxonomy can help to determine the difficulty level of tasks (Dagienė and Stupurienė, 2014). There is a slight mismatch between the difficulty level of the tasks used in the contest and students' actual abilities. To some extent the actual difficulty level seems to correlate with the classification in Bloom's taxonomy. It might hence be worthwhile to classify each task picked for a given age group before assigning the difficulty level (Dagienė *et al.*, 2014b). In other point, it is necessary to check whether or not the difficulty perceived by the pupils was substantially different from that estimated by those who proposed the tasks. This is important as a feedback in order to gain knowledge to be used both in ranking participants and in organising future editions of the contest. For this purpose, IRT was used (Bellettini *et al.*, 2015).

Contest management systems (CMS) are used for running the Bebras contests. Many countries had developed their own CMSs and discussing their functionality and other features. Currently, there are over ten of Bebras CMSs. Quality issues of CMSs are very important research questions within Bebras community. However, very little evidence is published at the moment. A Slovenian research team offered a model of a new management system which has to be:

(1) High performance.
(2) Scalable.
(3) Fault-tolerant.

The system was implemented and localised to three languages (English, Slovene and Serbian) (Kristan *et al.*, 2014).

### 3.3. *The Bebras Contest for Formal and/or Informal Informatics Education in Countries*

Striving to fulfil ambitious goals in developing modern informatics education, policy makers suggest various strategies. One of them is organising a range of gameful contests for all student age groups (Kalaš and Tomcsányiová, 2009; Kalaš, 2014). Reviewing the development of Europe informatics education, the Bebras challenge is seen as one of informal ways of introducing pupils to informatics topics. Informatics, the science of algorithmic processing, representation, storage and transmission of information, is an important discipline in the knowledge society and should be introduced to secondary or even to primary schools.

The challenge should help children to get interested in informatics and to stimulate thinking about contributions of informatics to science at the very beginning of school (Dagienė, 2010). The Bebras contest may play an important role in creation of school curricula from the "bottom", from basic elements and individual questions upon which broader informatics concepts may be illuminated (Vaníček, 2013a and 2014).

Many competitions in computing and information technology are mainly intended for talented students and focus on practical areas such as developing algorithms and programs. The Bebras challenge has instead provoked students to solve problems from

a broad range of informatics topics without any programming skills required. Usually many pupils enjoy friendly organised competitions, and the Bebras challenge can be used to attract children to the informatics domain covered by the contest tasks (Bell *et al.*, 2011; Bilbao *et al.*, 2014; Heintz *et al.*, 2015; Maytarattanakhon *et al.*, 2015; Sysło and Kwiatkowska, 2015). In another paper, Galik and Kalaš (2009) have stated that the Bebras is a contest focused on promoting interest in digital technologies and informatics for all students. Moreover, following many other researchers, the Bebras contest encourages students to use modern technologies in their learning activities more intensively and creatively (Sysło, 2011; Lonati *et al.*, 2011).

According to French case, the Bebras contest is a great tool for working and thinking about informatics education (Tort and Drot-Delange, 2013; Baron *et al.*, 2014). First, it is a way to raise questions among educational actors about informatics education. Teachers who engage their students in the contest come from other subject areas. When they spend one hour on the contest, they give a place to Informatics concepts and to computational thinking in their own teaching.

Informatics is still a male-dominated discipline, but results suggest that girls aged 10–13 manage equally well (or even better) than boys in this contest (Dagienė *et al.*, 2014a). In the lower secondary school age, there are no significant differences between boys and girls in their interests and performances (Kalaš and Tomcsányiová, 2009).

The results of several researchers indicate that both girls and boys can have a successful and rewarding experience exposed while solving the Bebras tasks (Dagienė *et al.*, 2015). Boys and girls show different results in tasks which require spatial thinking. It takes the same amount of time to solve a task but boys do it better. Pupils' performance of tasks increases with the age but boys of lower grades have almost equal results as girls of upper grades. However, the case study of Germany shows that the boys showed a significant better performance compared to the girls. Also, the pairs performed better than the singles (Hubwieser and Mühling, 2015).

A long-standing problem is discussed by several researchers: how to teach an introduction to theoretical informatics to secondary school pre-service and in-service teachers of informatics who lack sufficient mathematical background. An attractive method of solving five tasks from the Bebras contest was suggested to teachers in one research project (Bezáková and Winczer, 2011). Teachers were asked to play the task, and through that play they were guided to discover informatics concepts. Each new informatics concept was connected to real situations of a particular task.

Bebras tasks can be adopted or modified to many other activities, for example, to measure a difference in programming abilities (Ruf *et al.*, 2014), to stimulate students' online performance (Kabátová *et al.*, 2013).

## 4. A Model for Concept Based Learning

The "concept" can be described as extensive piece of information on particular object existing in human sense. The content of a concept can vary a lot as it depends on personal experience. Concepts of informatics are strongly related to our intention what basics

we would like to develop to children and at which age. In formal sciences, "concept" is defined as an abstract idea which generalises separate objects, defines attributes and some relations between objects.

Informatics concepts play a central role for understanding fundamentals of computers, information technology, software, hardware, and information systems. Concepts that should be introduced in general school education and represented in assignments and tasks, are still a subject of research and discussions (Hromkovič, 2006; Kalaš and Tomcsányiová, 2009; Vaníček, 2013b). It is problematic to decide what we should include in informatics education for primary and secondary schools. Some reasons for that could be as follows:

(1) Informatics is relatively young and rapidly evolving science.
(2) There is a variety of different practical applications of informatics and that overruns core theoretical and scientific concepts.
(3) There is no common agreement (framework) on what should be introduced in school from the theory of informatics, or whether it should be introduced at all.

It is important to bring informatics concepts to pupils in a very attractive way. Bebras challenge is one of the possibilities to bring informatics education in an informal way (Armoni and Gal-Ezer, 2014; Dagienė, 2011). The Bebras tasks are a major source in introducing informatics concepts. According to common agreed definition, each Bebras task should contain at least one informatics concept. The tasks have to concentrate on smaller learning items. Due to the independence from specific systems the focus of the tasks is not on working in real systems but on understanding of the principles, ideas and concepts that are involved.

Informatics concepts can be learned by a spiral way. The spiral cycle begins with a certain informatics concept, which is the key idea what we want to teach the pupils (Fig. 4). By adding a funny and interesting story, we create a task. By using gamification (application of game principles in non-game contexts), and by adding interactive components (dragging, dropping, etc.) we can develop a task for the Bebras challenge.

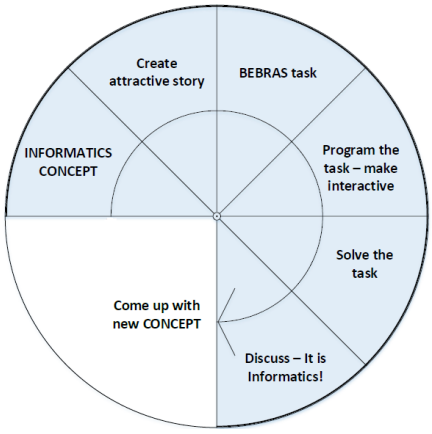


Fig. 4. From an informatics concept to a pupil understanding of it (from a teacher point of view).

The next big step is to solve a task (this is pupils' matter), however due to be of short time a pupil's main attention is paid to get the correct answer. The learning and understanding process of informatics concepts will come later, actually after practice to solve many of these tasks. A teacher's role is very important for strengthening the understanding of informatics concepts. Teachers can help pupils to clarify task solutions, to explain why it is informatics, to provide resources for readings and discussions.

Learning concepts at an early age are very important for deeper understanding of various informatics topics. The Bebras task focus on informatics concepts supports understanding of informatics phenomena and developing computational thinking. Development of Bebras tasks is actually based on operational definition of computational thinking which suggests that computational thinking is a problem-solving process that includes (but is not limited to) the following characteristics (ISTE&CSTA, 2011):

- Formulating problems in a way that enables us to use a computer and other tools to help to solve them.
- Logically organising and analysing data.
- Representing data through abstractions such as models and simulations.
- Automating solutions through algorithmic thinking (a series of ordered steps).
- Identifying, analysing, and implementing possible solutions with the goal of achieving the most efficient and effective combination of steps and resources.
- Generalising and transferring this problem solving process to a wide variety of problems.

The computer science teacher association in USA (CSTA) goes on by adding broader attitudes like ability to deal with complexity and open ended problems, tolerance for ambiguity, and ability to work with others to achieve a common goal.

Summarising, the operationalisation of computational thinking and informatics problem solving seems closely interwoven with ways to deeper learning linked to modern digital technologies and practices.

## Conclusions

Analysis of the 56 research papers on the Bebras challenge of informatics and computational thinking has discovered several evidences about the impact of the Bebras contest on the national curricula, especially on informatics education implementation in formal/informal levels. Learning through solving small pieces of concept-rich tasks, or a flipped learning, fits better to the digital era society.

The quality of the Bebras challenge is increasing by expanding activities for supporting informatics education and developing more powerful tasks. Actually goal is to develop rich tasks to have at their core, the opportunity to develop an understanding of, explore and employ informatics concepts. Several research groups have continued their work in this direction.

There is evidence about Bebras challenge as an effective tool in promoting problem solving skills and computational thinking. For the Bebras model, a connection to compu-

tational thinking is quite a new challenge and needs more efforts in preparation strategy for dealing with it. Thus, a good starting point could be the different points of view that the different professional groups have: pedagogic (teachers), pragmatic (designers of the challenge and tasks) or technical (implementers of tools).

Following the literature analysis and observing the Bebras contest implementation for more than ten years, a community building Bebras model was elaborated. The model bridges both international and national implementation levels and consists of various components.

Bebras tasks are cornerstones of the challenge. A lot of research questions can be raised in concern to developing the good Bebras tasks, their difficulty levels, validation, motivation pupils for learning, supporting informatics understanding, developing new tools for interactive tasks, etc.

This paper proposed an original development of informal informatics education model through questioning and solving tasks. Embracing concept-based learning means that we need to consider new design metaphors for future learning. However, we must remember that students (and teachers) will still need motivation to learn things. Therefore, this paper argues for greater motivation reached by attractive and interactive short tasks for learning informatics concepts. Future work will be related on students' long-term participating in the Bebras challenge in order to show evidence of the power of concept-based learning of informatics and computational thinking.

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