Challenge to Promote Deep Understanding in ICT

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SHORT PAPER

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Abstract. The international Bebras challenge on informatics and computational thinking is well-known in over fifty countries as an informal school activity. Running the contest annually for more than ten years, we have noticed that the students (and their teachers) consider the activities as a very exciting learning experience in problem solving and increased understanding of what lies beyond ICT. The crucial point of the challenge is the tasks: they focus mainly on the informatics (computer science) concepts and help in understanding beyond technology, they are short, attractive, and answerable in a few minutes; some of them have multiple-choice answers or are open-ended, and others have interactive components (solving by dragging, clicking, sorting, etc.). The performance of the Bebras challenge in many countries during the last years has shown a high acceptance by school students at all levels. The challenge also involves a fairly high number of female participants.

Keywords. ICT and human development problems, ICT and gender, Digital literacy, Deep learning, Informatics education, Problem solving.

1 Introduction

The status of informatics (computer science or computing) education as a deep understanding of information and communication technology (ICT) is unsatisfactory in many countries [1]. Although computers, applications and ICT in general are an increasingly natural part of the everyday work in schools, the focus is mainly oriented toward the basic digital literacy skills while the underlying principles are left uncovered.

Bringing informatics and ICT as a creative subject to schools through curriculum changes in the form of a formal track is essential, but it takes time especially when changes are reflected in a top-down way. Non-formal and informal ways are much faster and could involve a number of voluntary activities. We can enumerate an increased number of initiatives, e.g., CS Unplugged, code.org, Code academy, Hour of Code, aiming at making informatics and ICT creativity accessible to everyone.

The Bebras challenge on informatics and computational thinking is another similar activity [2]. The Bebras (*Beaver* in English) is an annual contest held in parallel in schools in many European countries and all over the world (e.g. Australia, Canada, France, Germany, Japan, Malaysia, Taiwan, USA). It provides motivated and game-

like tasks in the format of multiple-choice questions, open-ended problems, and interactive tasks where students answer by doing actions, dragging and dropping objects, drawing shapes, clicking on particular items, setting puzzles, writing answers in text boxes, etc. [3]. The name "Beaver" – in Lithuanian "Bebras" – was chosen in connection with the hard-working, intelligent, goal seeking and lively wild animal.

The Bebras challenge is developed for all primary, secondary and high school students. The contest is performed in schools on computers. Students should solve 18 to 24 tasks within 45 or 55 minutes. There are different task sets for the five defined age groups: Mini Beavers (grades 3-4), Benjamins (grades 5–6), Cadets (grades 7–8), Juniors (grades 9–10) and Seniors (grades 11–12). The participants are usually supervised by teachers who may integrate the contest in their teaching activities as well.

2 Some Statistics and the Methodology

The Bebras challenge is a medium to involve students of all grades in the task solving activities contest (the Bebras week in November). Actually, participation and discussions are more important aspects than competitiveness. Each Bebras task can both demonstrate an aspect of informatics knowledge and test the participant's ability of understanding ICT fundamentals [4]. The challenge is designed to promote informatics fundamentals for both boys and girls and to attract equal attention for both genders. A quite large number of girls took part in the contest last year (Table 1). Note however that some countries did not provide any data about gender, and 16% of Australian and 23% of UK participants were of unknown gender.

Table 1. Distribution of number of participants by countries and gender in the 2015 contest

Country	Total	Girls %	Country	Total	Girls %
Australia	16 925	~39	Latvia	1 209	-
Austria	17 641	46	Lithuania	24 709	43
Azerbaijan	4 065	44	Macedonia	19 608	47
Belorussia	53 587	-	Netherlands	21 086	44
Belgium	1 762	32	Pakistan	7 369	-
Bulgaria	474	28	Poland	13 392	-
Canada	10 288	40	Russia	24 543	-
Czechia	52 596	45	Serbia	30 823	-
Estonia	4 020	-	Slovakia	66 842	46
Finland	5 598	45	Slovenia	24 158	-
France	344 976	49	South Africa	28 543	44
Germany	248 084	44	Spain	711	-
Hungary	13 438	45	Sweden	6 206	56
Iceland	475	51	Switzerland	13 475	48
Iran	2967	-	Taiwan	27 864	45
Ireland	3 141	-	Turkey	13 784	49
Italy	12 017	32	Ukraine	93 820	49
Israel	~2 000	-	United Kingdom	55 967	~35
Japan	3 538	57	USA	39 213	-

The methodology in this research is based on quantitative statistical data and an overview of evidence presented in previous research in this area. The design of the Bebras challenge provides multiple kinds of data collection. These are statistics automatically collected during the online contest, and observation participants during competition.

The paper deals with a short reflection on the historical origin of twelve years of Bebras challenge, and connects this analysis with current dynamics within and across activities.

A detailed model on the Bebras Challenge on Informatics and Computational Thinking is developed and presented in paper [5]. An implementation of the model and results drawn from the model to reflect on the outcomes are discussed as well.

Bebras tasks are created and discussed during annually organized international workshops. The tasks should represent the main informatics areas: information comprehension, algorithms and programming, use of computer systems, discrete structures and patterns, logical puzzles, ICT and society. Each task is assigned one of three difficulty levels: hard, medium, or easy [4]. In one of the case studies, we found that the Bebras tasks are well-developed in terms of the cognitive domain (Bloom's taxonomy): a majority of the tasks fall into higher categories in understanding, applying, analysing, and evaluating [6].

The real challenge for researchers and educators is to design suitable, attractive, and promotional tasks. The tasks should cover different areas of informatics, be suitable for the age group and possible to answer in a short time, and they should do justice to the image of informatics.

3 From an ICT User to a Creative Thinker beyond Technology

A deep understanding must be based on a continuously developing level and involve a well-developed and rich basis of knowledge that has a relative complexity. Can we cultivate this kind of thinking with younger students as well? The answer should be positive, yes, if we would like to have a digitally literate and creative society. To reach this goal, we need to provide children with interesting, well-developed tasks and allow the children to explore these tasks.

A deep understanding of informatics (computer science) means that the concepts of the subject are well represented and well connected. Thus, a deep understanding of informatics involves the ability to understand basic principles of computing by recalling a set of connected main concepts. The deep thinking also involves the construction of new informatics (as well as ICT) concepts and is almost always based on students' previous knowledge.

When the Bebras contest was established in 2004, it focused mainly on ICT and computer fluency. Later on, it shifted to solving problems beyond ICT and promoting various types of thinking - algorithmic, logical, operational, based on informatics fundamentals and computing principles [7]. Essentially, the idea was to encourage children to learn ICT deeper, and to support the development of algorithmic thinking as well as computational thinking.

The term computational thinking was popularised in 2006 with Jeanette Wing's paper [8] but actually originated with Seymour Papert in 1996 [9]. Computational thinking is seen as a problem-solving process that includes formulating problems, representing data through abstractions, automating solutions, identifying, analysing, and implementing possible solutions, generalizing and transferring knowledge [10]. Computational thinking is an increasingly important focus in the curricula in schools around the world.

Our aspiration is to wrap up serious scientific problems of informatics and the basic concepts of ICT into playful tasks and inventive questions, thus attracting students' attention. It is not an easy matter to prepare tasks in such a way. As a general guideline, we find it more important to understand and handle the fundamentals and main concepts of informatics than recalling various technical details related to computers and ICT.

Understanding computing processes, controlling computations, calculations and estimations is more significant than being able to perform computations by ourselves. Information technology has to be understood at many levels, e. g., as a fundamental culture and not as a collection of buttons and instructions; as a development of ideas and not a finished work; as an explanation of the concepts, etc. We keep all these topics in mind while organizing the challenge and working on task preparation. The promoting idea of the Bebras challenge is not to test students' knowledge, but this contest can be used also for assessment of the students' achievements in computational thinking, especially over a longer time period [11].

4 How Girls Have Solved the Bebras Tasks

Several case studies originated from the results that girls aged 10–13, can manage equally well (or even better) as boys in the Bebras challenge [6, 12, 13]. Researchers from Lithuania, Finland, and Sweden have identified that, in the case of Benjamins, there is no great difference in the performance of boys and girls, and girls performed better than boys in several tasks, especially related to instructions and rules [13].

The pupils' performance in solving tasks increases with age. Furthermore, a case study from Germany shows that boys showed a significantly better performance compared to girls in upper grades [16]. A similar shifting between genders with increasing age has been noticed in the Lithuanian Bebras contests during many years. One of the main reasons for this shifting is the school-leaving programming exam, which is a prerequisite to enter the male dominated Computer Science related studies at our universities. More detailed investigations of this topic are needed. However, it appears extremely important to seek Bebras tasks that are attractive for girls of all ages [14, 15].

Last year 24709 students took part in the contest in Lithuania, out of which 2374 Mini Beavers, 7100 Benjamins, 5810 Cadets, 6114 Juniors, and 3311 Seniors. Figure 1 shows the total number of boys and girls in these age groups, together with the distributions of their total scores. The horizontal axis represents all the possible scores

(between 0 and 144 for the Mini group, and between 0 and 216 for all others); the vertical axis represents the number of boys and girls who got the respective score.

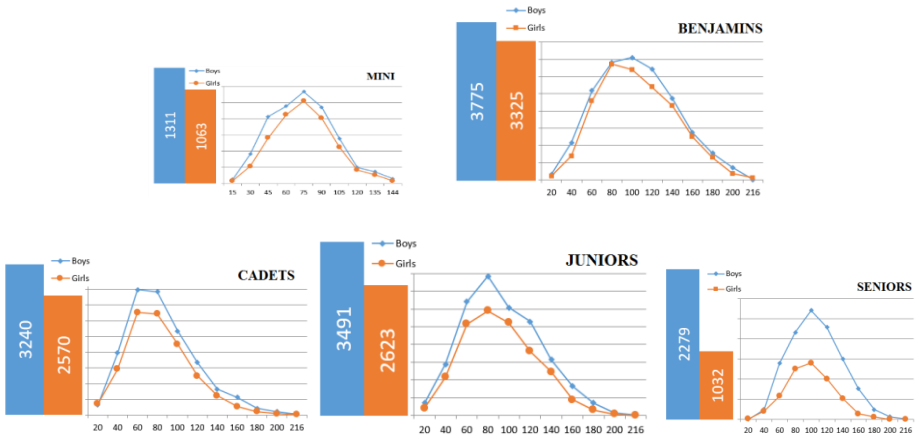

Fig. 1. Distributions of the scores: how successful boys and girls were when solving tasks

From the charts, we can notice that the girls in all groups, except for Seniors, are doing very well with a minimal difference from the boys' results. These results could be one of the influential factors disproving the misconception that informatics (computer science) is inherently a male study subject.

5 Future works

The large and multifaceted data, collected during the international Bebras challenge, gives the possibilities to analyse many interesting aspects, related to, e.g., students' understanding, difficulties and misconceptions in informatics based on different factors. We need to elaborate statistical models for measuring students' achievements and impact on thinking.

It is noticed that the non-curriculum approach provides an opportunity for grassroots influence on the formal curricula. Nowadays, top-down state-led education systems in many countries over the world struggle to efficiently deliver informatics and better ICT education in schools. Using nonformal and informal approaches for informatics education, we could make significant influence to the school curricula. An important issue for that goal is to estimate how effectively the materials, designed for outreach, e.g. the Bebras challenge, can be adapted to informatics curricula, the setting where a certain level of assessment will almost inevitably be required.

Another problematic issue, which needs to be researched, concerns the view of informatics and ICT as a male-dominated discipline. A long-term research is necessary in order to determine whether the girls, who had a successful introduction to informatics at an early age, exhibit less of the gender inhibiting stereotypes in informatics later in life.

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