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Invited Paper

# Informatics Concepts and Computational Thinking in K-12 Education: A Lithuanian Perspective

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**Abstract:** Informatics or Computer Science is important subject in nowadays school education. Informatics can be presented as a discipline for understanding technology in a deeper way – the understanding behind computer programs. Bringing Informatics to schools means preparing young people to be creators of information technology – not only to be users of technological devices. To achieve that, we need to introduce Informatics concepts to primary, basic (K-9) and secondary education (K-12). From the other side, we need to help people to solve problems by using technology and developing computational thinking in various areas. The paper presents a short overview of Informatics education at schools of Lithuania with focus on future modern Informatics and Information Technology curriculum for K-12 education. The importance of informal education of Informatics concepts and computational thinking through contests is discussed as well. Few examples of short tasks for understanding Informatics concepts and developing computational thinking skills are presented.

**Keywords:** informatics concepts, informatics curriculum, computational thinking, contest, Bebras challenge

## 1. Introduction

The Lithuanian educational system was gradually established and improved until it included every type and level of school that the country needed: pre-school education, and primary, basic, secondary, youth and vocational schools (**Fig. 1**). Education is free of charge and compulsory from the age of 6 to 16 years.

The pre-school age is from three to six. The children of these ages are taught in the kindergartens. In Lithuania, the kindergartens were supported by government, interested organizations, and by individual teachers. Since autumn 2016 all children at age 6 are required to attend pre-primary classes (at school or kindergarten). The primary school consists of four years. During the first four years, all the schools teach the same type of general education, which everyone has to complete. About half of the primary school teachers are enthusiasts at using information technology (PCs and mobile devices) in their lessons.

From approximately ages 11 to 16, students pursue their 6 years of education at basic school towards their certificate of lower secondary education. However the curriculum continues to be mainly academic still. Youth schools are meant for 12–16 year old adolescents that have not managed to adapt to studying at schools of general education, lack motivation or have no other choice because of the social situation that they face. Youth schools provide basic education and pre-vocational training.

There are a few different types of secondary schools: gymnasiums, pre-gymnasiums, full or short secondary, vocational and other schools. Secondary education curriculum consists of a block of compulsory education and a set of optional modules. Learners may choose to study according to general or expanded curricula. For their final two school years at secondary institutions, young adults may continue with general education or move on to vocational schools.

For indicating all school grades from pre-primary and the 1st through the 12th grade we will use the short form term K-12 (used in education and educational technology in the United States, Canada, and other countries). Research methods, used in this contribution, include analysis of informatics concepts, based on literature review and generalization of more than three-decade experience in Informatics education, survey of opinions of Infor-

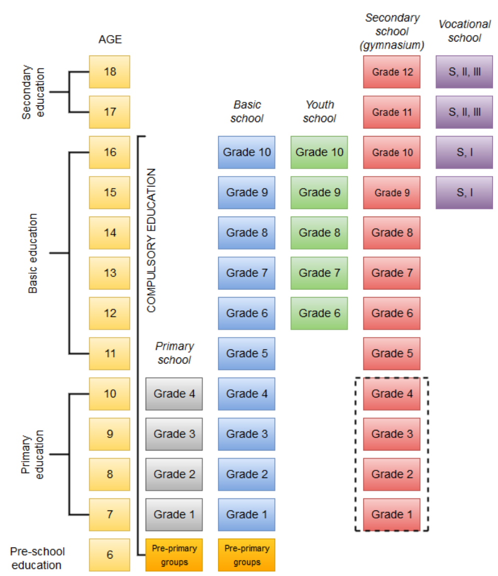


**Fig. 1** Education system in Lithuania.

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matics teachers, and interpretation of their responses.

## 2. Informatics Education in K-12 Schools

Computer Science (CS) education in high or upper secondary schools is entering the fifth decade of its existence in the world. Israel is one of the first countries which started to offer CS courses in high schools in the middle of the 1970s. Many European countries jumped onto this process a decade later – Lithuania is among them. To be prepared for the jobs of the 21st century, students must not only be digitally literate but also understand key concepts of CS. Students need to understand that CS combines both theoretical principles and application skills. They need to be capable of algorithmic thinking and of solving problems in other subject areas and in other areas of their lives.

In Lithuania, CS is named by Informatics (informatika). At the early beginning, teaching Informatics started with teaching programming. Programming is good way for problem solving transfer. Also, programming is a the best way to build a language for instructing (communicating with) a machine.

Informatics is developing its own fundamental concepts of communication, knowledge, data, interaction and information, and relating them to such phenomena as computation, language, and implementation. Informatics studies the representation, processing, and communication of information in natural and engineered systems. It has computational, cognitive and social aspects.

Informatics as a separate subject in comprehensive schools was taught in the majority of East European countries, where fundamental and academic trends of teaching are more prevalent up till now. Lithuania falls also under this category. Here, Informatics was introduced in 1986 in all types of upper secondary schools (11th and 12th grades). As a compulsory or partly compulsory subject it has been implemented in Belarus, Bulgaria, Czech Republic, Poland, Romania, Russia, Slovakia, and other countries ([1], [2], [3]). The course was changed permanently. Teaching about computers and training of programming skills were changed by practical use of information and communication technologies (ICT) for everyday activities.

Many countries started the 21st century with rising attention to the ICT implementation in education ([4], [5], [6]). Those countries which have Informatics as a separate subject usually treat ICT as a part of it; however, most of the time in the teaching process is assigned to the technology itself, and less for supporting the process of learning. Emphasizing the new course of "applied" Informatics, most of the countries, including Lithuania, have renamed it into information technologies (IT). Until now, there is no common international agreement on framework for Informatics and ICT in general education, although there are several discussions on this issue ([7], [8], [9], [10], [11]).

A common opinion is that fundamentals of algorithms and programming are the key concepts at school Informatics education. Especially learning programming and coding is becoming more and more popular among pupils with focus on web design and creating applications (apps) for mobile devices ([12], [13]). Then, what concepts should we include in Informatics education apart from algorithms and programming? How could we use information technology for collaborative learning to represent these concepts for students and ensure productive and sustainable learning?

Since 2005, the main attention in Lithuanian schools was paid to satisfy users' needs and to develop computer literacy. The Informatics/IT curricula in lower and upper secondary schools in Lithuania, the evaluation schemes and even the denominations have been changed; nevertheless it has remained a separate subject (information technologies or IT at the moment).

Besides, one of the most important components of IT is to make students of comprehensive schools ICT-literate. Today, IT courses are compulsory for the 5–10th grades for approximately 1 hour per week, respectively 35 hours per year (**Fig. 2**). There are some optional modules as well (e.g., programming). During the lessons, an integrative nature of the course is being stressed; students are prompted to see parallels with other subjects, to employ modern methods, to differentiate contents, etc. Students of upper secondary schools (11th and 12th grades) can choose advanced optional modules and have to learn the content defined in the course curriculum.

Teaching fundamentals of Informatics as a mandatory part has become quite poor. Students get familiar with the basic knowledge on Informatics in grades 5 and 6, when they have a Logo or Scratch course and in grades 9 and 10 with focus on under-

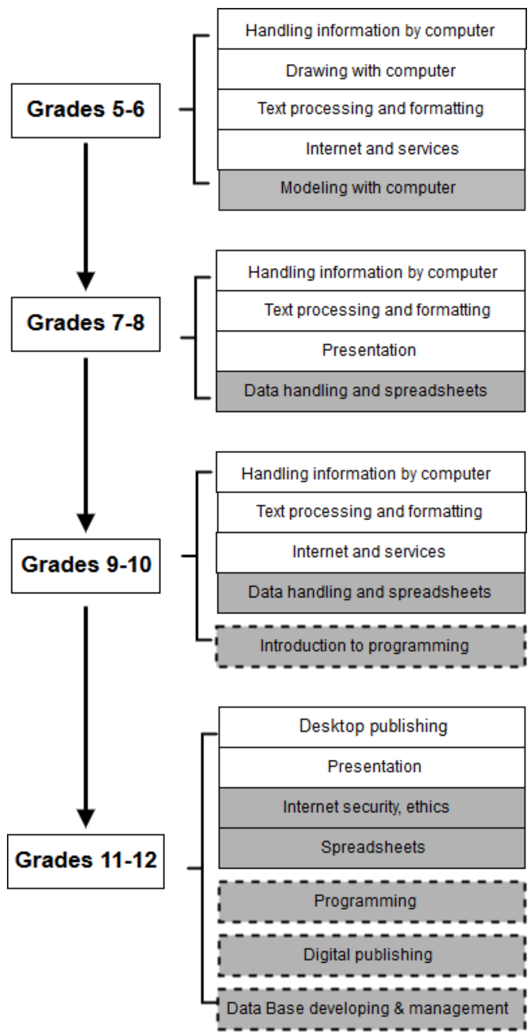


**Fig. 2** Scope of IT/Informatics curriculum in grades 5–12 of schools in Lithuania (grey colored boxes represent Informatics related topics).

standing simple algorithms and computer programs. The teaching process in Lithuania depends very closely on the knowledge and activeness of the teachers themselves. The optional modules on programming and related topics are available at upper secondary schools and in some schools also in lower grades.

The Joint Informatics Europe – ACM Europe Report, released in April 2013 [14], is what spurred action in the Europe Union concerning Informatics education. It was developed by a group of experts from academia and industry representing the two principal scientific societies in the field, Informatics Europe and the Association for Computing Machinery (ACM). The report covered a broad range of experiences and good practices in various countries.

The report defined a blueprint for European digital literacy and Informatics curricula, and it explained why they are critical to countries' economy. Based on the reports' recommendations, the Informatics curricula can be developed taking into account constraints of individual countries, such as a lack of computers, internet connections, or qualified teachers.

France and Finland are examples of countries, where Informatics was not taught as an independent subject matter, but introduced as a tool for other subject matters [15]. However in 2012, France introduced an Informatics course in upper secondary school in the Science field of study (for 12th grade) and it focuses on Informatics fundamentals. Finland, Italy and more countries have been developing an Informatics curricula for K-12 education.

## 3. Teacher Survey on IT/Informatics Curriculum

Teachers are one of the most important keyplayers in the education system, and they implement and deliver the curricula at school so their opinion on the Informatics curriculum is very important for future improvements. Teachers also need to know how to recognize and solve problems that may arise within the classroom when they deliver the curriculum. A qualitative approach was used in this study in order to gather data in response to the research questions, and the information itself was secured through a questionnaire that contained 9 multiple-choice and 3 open-ended questions. Four questions suggest the elaboration of the answer part. The questionnaire was distributed in June 2015. Survey designers attained content validity by developing questions that ask about the components of IT/Informatics curricula and their implementation. The main purpose of this survey was to collect teachers' opinions concerning the current IT/Informatics curricula (developed in 2005).

We got answers from 337 IT/Informatics teachers (about 35 percent of all IT/Informatics teachers). 90% of the teachers have more than 6 years practice in teaching this discipline, while about 3 percent of the teachers have less than 3 years practice.

**Table 1** indicates that the great majority of IT/Informatics teachers are not satisfied with the IT/Informatics curriculum in its current state (released in 2005).

The teachers were asked to state how IT/Informatics curriculum should be improved or changed (**Table 2**).

As we see, many teachers emphasized teaching programming

**Table 1** Teachers' results of ranking satisfaction with the current IT/Informatics curriculum.

| Perception | Frequency | % |
|---|---|---|
| Very satisfied | 4 | 1.2 |
| Satisfied | 71 | 21.1 |
| Unsure | 3 | 0.9 |
| Dissatisfied | 222 | 65.9 |
| Very dissatisfied | 37 | 11 |

**Table 2** Teachers' suggestions for improving IT/Informatics curricula.

| Perception | % |
|---|---|
| IT (Informatics) subject must be compulsory since grade 3 of primary school (now it is compulsory from grade 5). | 36 |
| Emphasize teaching security of internet, save passwords, ethics, etc. | 8 |
| Include robotics elements and mobile technologies. | 22 |
| Need more teaching hours. 1 per week is not enough. In grades 7–8 there 1 hour per week is designed for integration with other subjects (but in reality it doesn't work). | 23 |
| Making presentation should be shifted from grade 7 to grade 5, because various subject teachers request it in early years. | 11 |
| More programming in grades 7–8. | 25 |
| IT/Informatics content in grades 9–10 is too condense, many students don't remember fundamentals because of Informatics course break in grade 8. | 37 |
| More programming and algorithmic thinking topics are needed. | 18 |
| IT/Informatics matura exam focuses on programming (50% of the content). It is difficult for students who don't learn Informatics continually from early years. | 40 |
| Textbooks and tutorials for students are too old (10 years and older). | 13 |

**Table 3** Teachers' opinion about optional modules.

| Opinion | Frequency |
|---|---|
| No need to have three modules because in any school there are not full groups of pupils who want to learn these modules so in final there are only one module. | 10 |
| Programming module should be compulsory not optional as it is now. | 24 |
| Matura exam must be based not only on programming module but on all three modules. | 18 |

at early stages and continuously. Teachers noticed that many IT related topics should be taught at younger age so that students can use these skills for their better learning of other subjects. The three optional modules (Programming, Desktop publishing, and Data base developing and management) for upper secondary level were discussed in detail (**Table 3**).

Teachers expressed their attitude concerning Informatics as a fundamental subject compulsory for students of all age: 161 teachers strongly agreed with that.

Almost all IT/Informatics teachers agreed that basic knowledge of Informatics should be delivered for every student at K-12 because societies need more technology creators, not only users. Physics for example explains the laws of reality, and Informatics explains the laws of virtual reality. We need to think algorithmically when the analyze the data from the daily life, we need to think computationally when we solve problems.

## 4. A Revival of Informatics Curriculum

Many countries, at least in Europe, are working on developing new Informatics (CS, Computing, IT, etc.) curricula ([16], [17], [18], [19], [20]). The White Paper by the CSTA [21] lists a number of challenges and requirements that must be met if we want to succeed in improving Informatics education.

In view of the recent developments in many countries, for example in the USA and in the UK, it appears that computer science education in primary or secondary schools (K-12) has reached a significant turning point, shifting its focus from ICT-oriented to rigorous computer science concepts [22]. A new Informatics/IT curricula for Lithuanian schools have been designed to meet the following challenges:

- Students should acquire a broad overview of the field of Informatics (Computer Science);
- Instruction should focus on problem solving;
- Developing algorithmic and computational thinking should be one of the most important goals;
- Informatics should be taught independently of specific application software, programming languages, and environments;
- Informatics/IT should be taught using real-world problem situations;
- Informatics education should provide a solid background for the professional use of computers in other disciplines.

The new Informatics curriculum benefits very much from our experience in teaching Informatics in schools for more than 30 years. In particular, it takes the hours assigned to the present IT curriculum and renews or makes new components of the curriculum. Informatics is going to unify the names of all stand-alone IT subjects and include components of digital literacy, information processing, security, etc. as well.

Informatics is a compulsory subject in basic school (1 hour a week for 5th and 6th grade; 1 hour a week for 7th and 8th grade plus 1 hour of integrated IT course; 1 hour a week for 9th and 10th grade). Informatics is an optional subject in upper secondary schools (3 hours a week for 11th and 12th grade) and students may take the final examination (matura) in Informatics.

We have been very lucky that the present IT/Informatics curriculum already includes Informatics subject on each education level and we have only had to modify and extend components and modules of the existing IT/Informatics curriculum. The same applies to the hours of instruction. Needless to say that otherwise it would be very difficult or impossible to convince the education authorities that the national curriculum needs such changes in the area which is unfortunately not of the highest priority on the official agenda. We would like to say that several countries (e.g., Poland, Latvia, Netherlands) working independently renewed their Informatics curriculum nearly in the same way and stacked to a very similar framework of Informatics curriculum. The renewed Informatics curriculum consists of several parts. One part is the same for all levels of K-12 education. It includes unified aims which define five knowledge areas in the form of general requirements.

(1) *Information*. Understanding and analysis of problems – logical and abstract thinking; algorithmic thinking, algorithms and representation of information;
(2) *Digital technologies*. Using computers, digital devices, and computer networks – principles of functioning of computers, digital devices, and computer networks; performing calculations and executing programs;
(3) *Algorithms and programming*. Programing and problem solving by using computers and other digital devices – designing and programming algorithms; organizing, searching and sharing information; utilizing computer applications;
(4) *Virtual communication*. Developing social competences – communication and cooperation, in particular in virtual environments; project based learning; taking various roles in group projects.
(5) *Security, ethics, low principles*. Observing law and security principles and regulations – respecting privacy of personal information, intellectual property, data security, netiquette, and social norms; positive and negative impact of technology on culture, social life and security.

The biggest part of the curriculum consists of detailed attainment guidelines. The guidelines define the content adequately to the school level (grouped by two grades, e.g., 5th and 6th, 7th and 8th). Thus learning objectives are defined that identify the specific Informatics concepts and skills students should learn and achieve in a spiral fashion through the several levels of their education.

## 5. From Algorithms to Computational Thinking

Half a century ago, Informatics curriculum mainly focused on algorithms and programming (or coding). The role of programming is two folded. From one hand, A. Perlis wrote in 1962 that everyone should learn to program and Mark Prensky declared a few years ago that “The True 21st Century Literacy Is Programming” ([23]). From the other hand, we should avoid ‘the equation’: computer science = programming which is accused of killing interest in computer science among school students in 1990. Not all students will become professional programmers but writing their own programs, individually or in a group, they practice creative and computational thinking, and gain skills of the digital era useful for professional and personal life. They should also get some experience in programming of various digital instruments, such as toys, robots, and vending machines.

Traditionally, a programming language is a language of computer science in a sense that it is a tool for expressing algorithms and to communicate them to computers and also to other programmers. However, we should remember that “Informatics should be taught independently of specific application software and programming languages and environments.” We have extended the meaning of the terms ‘program’ and ‘programming’ to see them in a wider context of using computers to solve problems which are not necessarily algorithmic in nature and introducing all students to computational thinking. There are plenty of opportunities to communicate with a computer by means of programs which are created by other programs, instead of writing the users’ own programs.

Problem solving and computational thinking are important abilities that school students should acquire in their daily activities by using different means and techniques. J. Wing has made a wide-used definition [24]: Computational thinking involves solving problems, designing systems, and understanding human behavior, by drawing on the concepts fundamental to computer science. Later (in 2011) the topics were revised and computational thinking was defined as the thought process involved in formulating problems and their solutions [25].

In a broader sense, computational thinking includes many components of problem solving: Formulation and restatement of tasks; Data analysis; Decomposition; Modeling and simulation; Recognition of pattern solution components; Automation of decisions; Efficient use of resources; and Abstraction of decision process. Computational thinking skills are supported and enhanced by a number of dispositions or attitudes that are essential dimensions of Informatics and digital literacy [26].

The main difference between using information technologies and thinking computationally is in going beyond using information technologies tools and information towards creating tools and information. It reminds of our distinction between Informatics (as creation of programs, computers, theories, etc.) and Information technologies (as applying informatics tools). The creation of tools (e.g., programs) and new information requires thinking processes about how to use abstraction and manipulate data and many other computer science and computing concepts, ideas, and mental tools of computational thinking.

## 6. Bebras Challenge —— A Way to Introduce Informatics Concepts and Computational Thinking

Computational thinking is tightly connected to learning Informatics concepts. For example, describing an object in an algorithmic way, using a formal language to do this, managing information flows and using machines characterize the computational thinking [15].

Informatics concepts play a central role for understanding fundamentals of computers, information technologies, software, hardware and other devices. However, in practice, very often the training of skills in application software is given much more room at schools than to discover and to go deeper into concepts of Informatics.

A "concept" can be understood as extensive information on a particular object, existing in human mind. The content of a concept can vary a lot as it depends on personal experience. Concepts of Informatics are tightly related with our intensions: what we would like to teach at school. In formal sciences "concept" is defined as an abstract idea which generalizes separate objects, and defines attributes and relations between objects. A concept can be defined as a set of objects having common attributes.

It is important to bring Informatics concepts to pupils in a very attractive way. One of the possibilies could be to use the Bebras challenge during the Informatics lesson in informal way [27].

A challenge-contest on Informatics fundamentals, Bebras, for all school pupils was established in 2004 and organized in Lithuania. The main goals of the Bebras challenge are to promote pupils' interest in Informatics from the very beginning of school and lead them to develop computational thinking abilities. Actually, the idea was to involve pupils into Informatics task solving activities and to use computational thinking and modern technologies more intensively and creatively [28].

The challenge-contest focuses on five age groups (some countries have three or four groups) with different task collections for each group. The youngest participants are primary school students (8–9 years old) and the oldest participants are senior high school students (17–19 years old). It is an Informatics problem-solving contest with tasks that require problem-solving and algorithmic thinking which constitute a part of the computational thinking development.

The tasks are short, answerable in a few minutes through a computerized 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, school students are required to think in and about information, discrete structures, computation, data processing, data visualization, and they should use algorithmic as well as programming concepts. A Bebras task can both demonstrate an aspect of Informatics and test the participant's ability of understanding Informatics fundamentals [26].

Informatics concepts learning cycle (the spiral cycle) begins with a certain Informatics concept, which is the key idea what we want to teach the pupils (**Fig. 3**). 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 create a task for the Bebras challenge. The next step is to solve the task (this is the pupils' task), by understanding the task rather than just guessing. Teachers can help pupils to understand the tasks after the solving time by explaining why it is Informatics and why it is important.

The 12th world wide Bebras week took place in 40 countries in November 9–13, 2015. In Lithuania, 24,709 students from

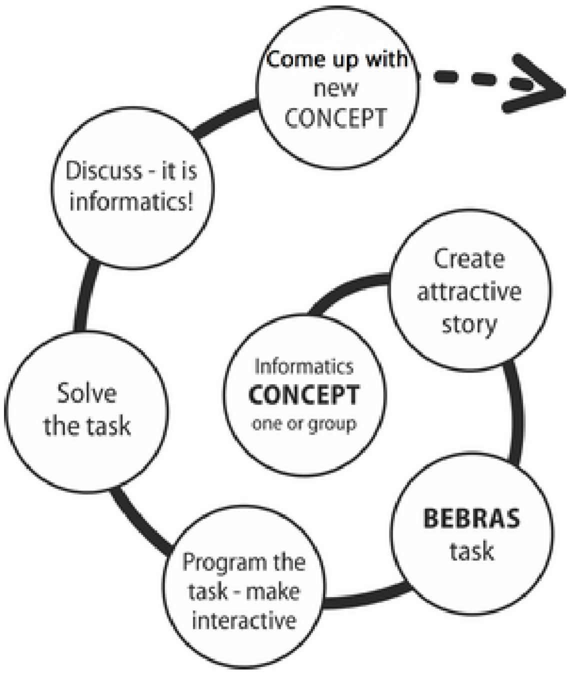


**Fig. 3** From Informatics concepts to students understanding of it (from teacher's point of view).

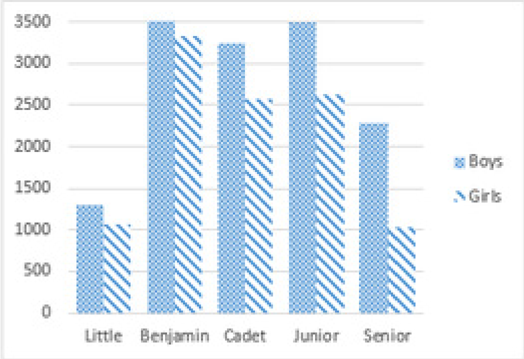


**Fig. 4** Number of participants in Bebras (2015).

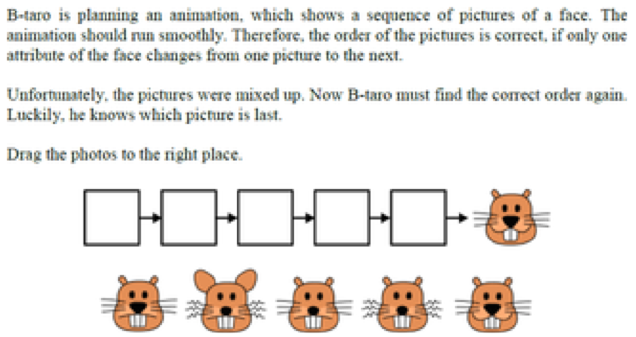


**Fig. 5** Ancestor – One of the Bebras tasks.

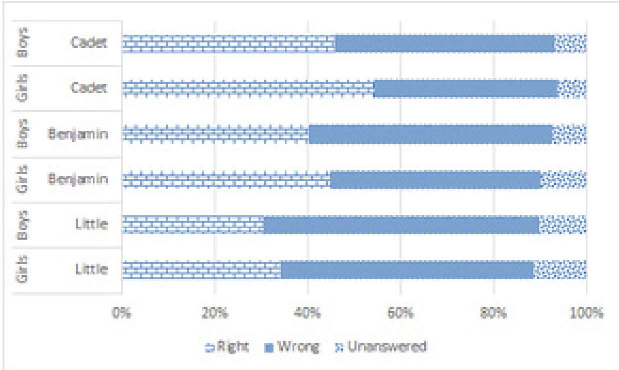


**Fig. 6** Result of pupil's performance of task "Ancestor".

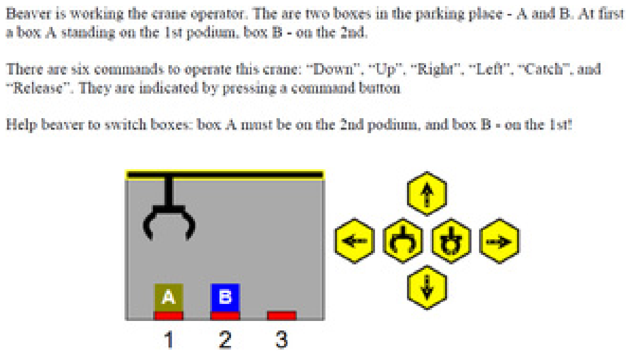


**Fig. 7** Crane operating – A Bebras interactive task.

531 schools participated (**Fig. 4**). During the Bebras week, after solving the tasks, the students were asked to select the most interesting tasks.

The most interesting task for 3rd–8th grade students was "Ancestor" (selected by 718 of 9,577 students participating in the ranking process after the contest). For the 3rd–6th grades the most interesting task was "Crane operating" (744 of 6,070 students participated in ranking process after contest). Both tasks were suggested by Japan and was selected as good Bebras tasks to use.

The Ancestor task deals with data structure concepts, in particular with class which is a very important concept in object oriented programming (**Fig. 5**). In order to find the differences between the pictures, students have to find about the essential attributes of the depicted faces first. The list of attributes and their possible values is:
*ears*: small, large
*mouth*: plain, smile
*nose*: small, large
*number of teeth*: 2, 3
*whiskers*: curly, straight
For instance, students can describe the first face as a list of attribute-value pairs:
(*ears*: small; *mouth*: plain; *nose*: large; *number of teeth*: 3; *whiskers*: straight).

Nowadays, computers are not bad at processing images, like finding differences between them. But it is much easier for computers to work on structured data like lists of attribute-value pairs. In Informatics, it is very usual to model things from the real world as "objects" that have attributes and values. Objects with the same set of attributes (like all beaver faces) are then summarized into a "class". But what if the computer has to deal with a beaver face that has an attribute so far unknown? The computer might get in trouble.

This task was solved by the students of grades 3–8. Students spend 104 second on average to solve this task. In each group girls showed a little bit better results than boys. The percentage of right answers is growing up with the age of the participants. The worst results are found in the Little Beaver group (grade 3–4) (**Fig. 6**).

The another example of a Bebras task is related to the algorithm concept (**Fig. 7**). A sequentially structured algorithm for exchanging two objects is used in this task.

In a sequential algorithm two objects can only be changed if one of the objects is placed on an extra place. If the exchange is done simultaneously, for example by two concurrent working robots, the extra place is not required. Most of the computers still work with sequentially executed programs, so each exchange operation in the memory of the computer needs an extra space to deposit intermediately the value of one of the two values to be exchanged.

This task was solved by the students of grades 3–6. Students spend 128 second on average to solve this task. In each group, girls showed a little bit better results (**Fig. 8**).

Results of both examples have showed that not only boys but also girls are interested in understanding Informatics. Children are able to solve the tasks when they are presented in very attractive way.

## 7. Concluding Remarks

Informatics education has emerged recently in many countries.

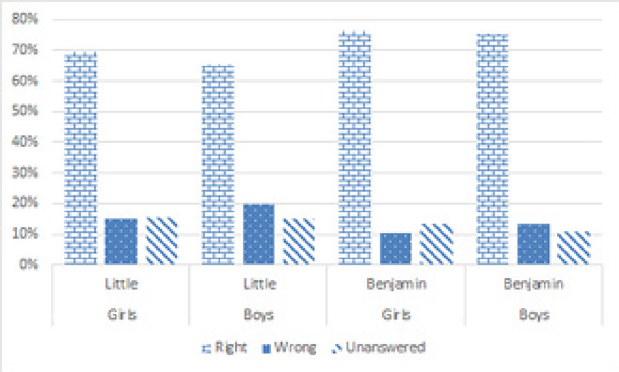


**Fig. 8** Students' performance results of task "Crane operating".

The young generation is seeking to be creators and developers of new technologies. Many countries started to establish Informatics education in lower and upper secondary schools and even in primary grades or kindergarten. Some countries have revised or revived IT or connected disciplines which their schools have taught. Lithuania is one of the few countries where Informatics education has been supported (at least has not been stopped) for more than three decades.

For the successful implementation of Informatics as a school discipline, the following actions should be taken into account: 1) balance of Informatics curriculum in accordance of theoretical and practical parts (concepts and skills); 2) stimulation of discussions among different groups of interests (teachers, parents, students, politicians, stakeholders, etc.) on Informatics topics and teaching; 3) reflection of international computer science education directions and considering national peculiarities; 4) teachers' competencies and motivation to keep learning new things; 5) tight connection between formal and informal Informatics education.

Informatics education should be taken seriously and combine various forces. To obtain deep understanding of Informatics concepts, formal lessons are not enough attractive for keeping students' motivation. Students should be encouraged to play with these Informatics concepts in their everyday life.

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