Informatics concepts in secondary school education: What should we teach?

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Abstract
This paper deals with informatics and/or information technology in secondary school education. Since its introduction, either as a separate subject or in an integrated way, the question about its contribution to general education still stays open and finds new responses. Many researchers agree that algorithms and programming are key concepts in informatics education. However, which further concepts must be included in a comprehensive informatics curriculum and how can we find a balance between theoretical informatics fundamentals and application levels? Finding a common model would help to achieve better results in informatics education on an national and international level. It is important to provide students with skills in using computer technologies and understanding them as well. Finally, results of a survey of Lithuanian informatics teachers' opinions on topics informatics at school level are presented. The paper concludes with a proposal to harmonize informatics contents on a transnational level.

Keywords
Informatics concepts, informatics fundamentals, teaching informatics, informatics curriculum, information technology

INTRODUCTION
in the early 1980s, many countries introduced Informatics as a school subject. Its development is characterized by permanent changes in hardware, software, didactical approaches and key topics of informatics. Moreover, this varies from country to country considerably.

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 also falls under this category. Here, informatics was introduced in 1986 in all types of secondary schools. As a compulsory or partly compulsory subject it has been implemented Belarus, Bulgaria, Czech Republic, Latvia, Poland, Romania, Russia, Slovak Republic, Hungary, Germany, and other countries (Sendova, Azalov, Muirhead, 1995; Hawkridge, 1996). The course is changed permanently. At the beginning teaching about computers and training of programming skills got more attention, while nowadays a shift to the practical use of ICT (-applications) for teaching and learning can be observed.

In today's world all the countries pay a rising attention to the ICT implementation in education (OECD, 2001; OECD 2010; OECD/PISA 2010). 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 technology (IT).

The informatics/IT curricula in lower and upper secondary Lithuanian schools, the evaluation schemes and even the denominations have been changed; nevertheless it has remained a separate subject (now called "information technology"). Besides, one of the most important components of IT is to make students of comprehensive schools ICT-literate. Today, information technology courses are compulsory for the 5-10th grades of lower secondary (named basic) schools for approximately 1 hour per week, respectively 35 hours per year. There are some optional modules as well (e.g. programming). 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. 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.

Until now, there is no common international agreement on a accepted framework for informatics and ICT in general education, although there are several discussions on this issue (Dagiene, Futschek, 2010; Micheuz, 2008; Hromkovic, 2006; Dagiene, 2006; Micheuz, 2005; Schubert, 2004).

Almost a common opinion is that fundamentals of algorithms and programming are the key concepts in school informatics education. Then, what concepts should we include in informatics education apart from algorithms and programming? What is the ratio of programming concepts and information technology concepts and their application? How could we use information technology for collaborative learning to represent these concepts for students and ensure productive and sustainable learning? The paper discusses these questions, considering formal and informal education.

Research methods, used in this contribution, include analysis of informatics and information technology concepts, based on literature review and generalization of more than two-decade experience in informatics education, survey of opinions of informatics teachers, and interpretation of their responses.

KEY INFORMATICS CONCEPTS

Concepts of informatics play a central role in all curricula and standards for informatics education at schools. However, in practice, very often the training of skills in application software is given much more room at schools than to the understanding of fundamental 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, defines attributes and relations between objects. A concept can be defined as a set of objects having common attributes.

Curricula and standards for secondary schools describe learning contents and methods of learning. In the field of informatics some international guidelines were developed that, for a larger group of countries, define which content areas and which way of learning can be appropriate, e.g. the UNESCO/IFIP curriculum (Anderson, Weert, 2002; Unesco, 2005), the ACM K-12 curriculum (A Model..., 2003; Tucker, 2003). The German Society for Informatics GI (2008) standard as well

as the Lithuanian and the Austrian informatics curricula are discussed in the paper (Dagiene, Futschek, 2010).

The ACM K–12 curriculum report refers to the idea of information technology fluency of the National Research Council and describes ten basic ideas that underlie modern computers, networks and information (National Research Council, 1999). A computer-fluent student would master information technology on three orthogonal axes: concepts, capabilities, and skills. The ten basic ideas (concepts) are:
1) computer organization, 2) information systems, 3) networks, 4) digital representation of information, 5) information organization, 6) modelling and abstraction, 7) algorithmic thinking and programming, 8) universality, 9) limitations of information technology, and 10) societal impact of information technology.

The educational standards developed by the German Society for Informatics GI (GI, 2008) is quite new and has fresh ideas for informatics education in secondary schools, grades 5 to 10. The GI standard proposed two main areas for teaching informatics: content area and process area. Each content area can be combined with each process area together with examples of typical tasks that are suitable for secondary school education. The content part covers five basic concepts: a) information and data, b) algorithms, c) languages and automata, d) informatics systems, e) informatics, man and society, while the process area promotes actions, combined with concepts, e.g. modelling and implementing, representing and interpreting, structuring and networking, communicating and cooperating, arguing and evaluating. More detailed initiatives in terms of reviewing and structuring informatics education are presented in (Micheuz, 2008).

The main concepts of informatics that should be introduced in general school education and represented in assignments and tasks, are still a subject of research and discussions (Cartelli, 2010; Hromkovic, 2008, Kalas, 2009). It is really problematic to decide what we should include in informatics and information technology education for secondary schools. Some reasons for that could be as follows:

1) Informatics (including information technology) is quite a new and rapidly evolving science;
2) There is a variety of different practical applications of informatics which overruns the core of theoretical and scientific concepts;
3) There is no common consent (framework) about the extent of teaching theoretical aspects of informatics, and when and if at all it should be taught at school level.

Collaboration in International Informatics and Computer Fluency contest BEBRAS reveals six concepts important for general informatics education (Dagiene, Futschek, 2009):

- *Information*: conception of information, its representation (symbolic, numerical, graphical), encoding, encrypting;
- *Algorithms*: action formalization, action description according to certain rules;
- *Computer systems and their application*: interaction of computer components, development, common principles of program functionality, search engines, etc.;
- *Structures and patterns*: components of discrete mathematics, elements of combinatorics and actions with them;
- *Social effect of technologies*: cognitive, legal, ethical, cultural, integral aspects of information and communication technologies;

- *Informatics and information technology puzzles*: logical games, mind maps, used to develop technology-based skills.

In his research, Hromkovic presents several components that represent the basics of informatics and should be taught at school (Hromkovic, 2006). They include programming, computability, and automata theory. Automata theory, as well as the graph theory, can be visually represented by simple schemes. It can be used to present many examples from everyday life. For example, the automata theory can be considered as part of the concept of structures and patterns presented above.

It has been agreed on some of the main concepts to be taught in general education, e.g. algorithms and programming (as a separate or integral part of algorithm construction) are that of the most important concepts of informatics. It could be decomposed into important smaller concepts, e.g. data, variable, cycle, procedure, object, class, etc. Structures and patterns are also important concepts in informatics. And last but not least, the term and building block "information" is undoubtedly within the scope of informatics and information technology.

Computer systems are more difficult to describe (even the concept name itself "computer systems" is not unambiguous, it can be understood as application of information systems, but not as theoretical grounds). When the concept is not clear enough, it becomes difficult to use and especially to teach (usually much more attention is paid to the aspects of applications).

The social aspect of technology is not an unambiguous concept, so it cannot be clearly considered as a separate concept of informatics. No doubt, this topic is very important in our society, but there are still not enough educational examples and systematization for this topic in practice and research.

An important issue is how we present the main informatics and information technology concepts to students. Puzzles and logical games could help to attract students, raise their motivation. So, they should be used to express the core scientific concepts.

Based on these reflections, we propose a general scheme of key informatics concepts for schools: 1) information and data, 2) programming, 3) modelling and automata, 4) logics and computer, 5) structures and patterns, 6) computer systems and networks, 7) society and informatics (Fig. 1).

If we were able to find a clear answer to the question about the fundamentals of informatics and information technology, it would be easier to develop a valid taxonomy of concepts as a sound basis of a modern framework of informatics and information technology.

The representation of information by a code and distinction between the form of this representation and its significance, e.g. between syntax and semantics, are fundamental concepts in informatics. This concept includes the notion of information, information representation forms (symbolic, numerical, graphical), the differences between information and data, the main principles of data handling by computers, character encoding in computers, measurement, and other issues.

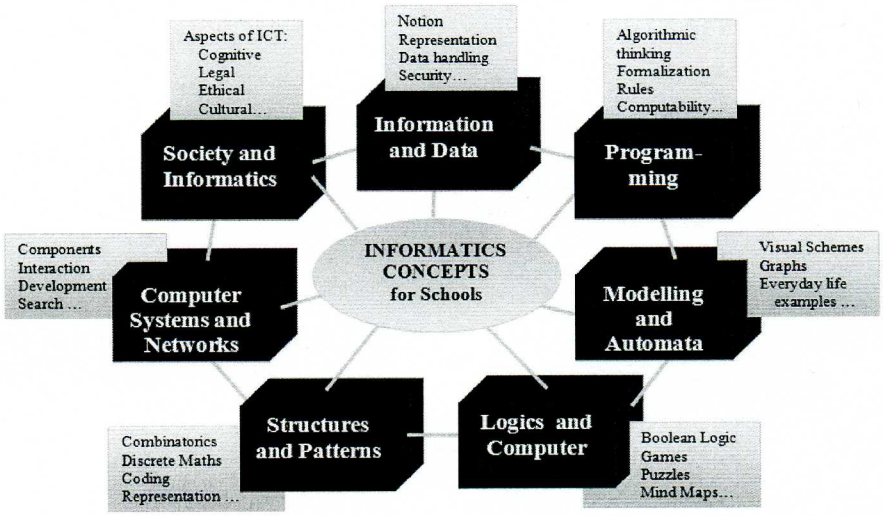

Figure 1. Summarized key informatics concepts for schools

No doubt, the concept of algorithm is fundamental in introductory informatics. We can consider the concept of algorithm independently of the software context. Other key issues in the context of algorithms include the question whether an algorithm holds, whether a problem is decidable, computable, etc. At first view, such questions seem to be too complex for secondary education, but it depends on teachers' qualification to present simple examples that can be formulated intuitively and used as introductory topics at secondary school level.

Modelling needs abstraction. Certain aspects of a task are deemed to be relevant, and are taken into account in the model, while other aspects are treated as irrelevant and thus ignored. What is deemed to be relevant or irrelevant is of fundamental importance and depends on the purpose of modelling. The state concept is usually attached to a model: a system that can be in various defined states and that switches from one to another as a result of defined events is called an automaton. If each subsequent state is uniquely determined by the current state and the event in question, the automaton is deterministic and its behaviour can be forecasted.

The logical fundamentals of computers are an important concept of informatics as well. However, not to fall down just into Boolean algebra, logical schemes, triggers, etc., the main aspects of logical thinking and problem solving are also included in this category, i.e. solving and developing puzzles, logical games, or even creating mind maps.

Structures and patterns include mathematical basics of informatics, combinatorics, arrangements, coding, representation, including object-relational approaches, as well as speech and image recognition.

Computer systems and networks are between informatics and engineering, and, as mentioned above, they should involve theoretical aspects of systems, components, their interaction and development, network architecture, and search issues.

Society and informatics are a cross-discipline concept, but it involves very important informatics issues, i.e., privacy, security, ethical, cultural aspects of ICT (development as well as use) and historical aspects of informatics. According to Laszlo Böszörmenyi, "In an increasingly abstract world [...] informatics education

could be the vehicle for providing a bridge to reality, a context for understanding; and the historical aspects of informatics could be an essential part of such educational process" (Böszörmenyi, 2008).

SURVEY OF TEACHERS' OPINION

A survey of teachers' opinion was conducted in Lithuania last year in order to get to know which concepts of informatics and information technologies are supported by most of the teachers. There were 115 respondents from lower and upper secondary schools throughout the country teaching information technology (and some elements of informatics) in grades 5-12.

The question was "How important do you find the following topics to be taught in schools (it doesn't matter which grade and age)?" The teachers valued each topic (concept) to scale "quite important", "medium important", "almost not important". Further, they could choose the option "I do not have my opinion" (generally less than 5% used this opportunity; therefore this response iis not incluided in the results.

The results show that teachers think teaching information, computer systems and networks, text processing and spreadsheets to be most useful for pupils and they mainly focus on that (Fig. 2).

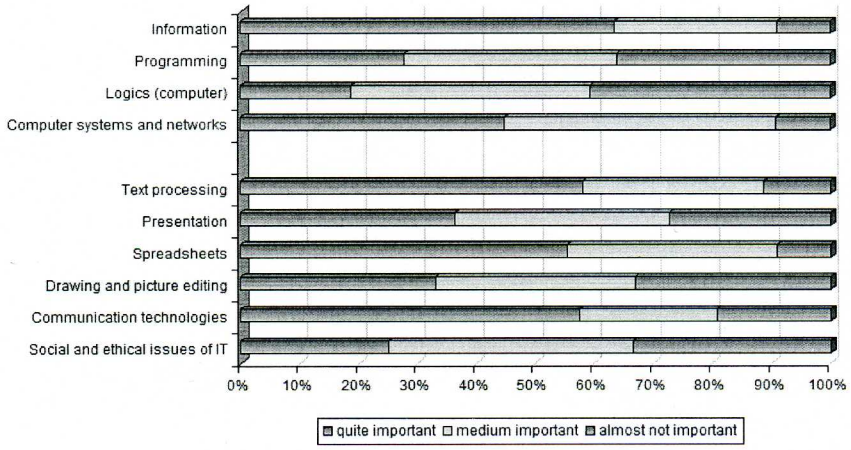

Figure 2. Results of teachers' opinions on the question "How important do you find the following topics to be taught in schools?"

Interpretation of the plain quantitative data is not an easy task. We collaborated with teachers for a long time, therefore it is possible to understand their attitudes and believes. For example, taking into account that the concept "Information" has been included into the Lithuanian curriculum from the very beginning of introducing informatics in schools (more than twenty years) - since that time a lot of efforts have been made in teachers' training, and much methodological material has been developed. School textbooks include theoretical topics on information and relate them with practical skills. So it is easy to understand why most teachers think of information as an important concept of informatics education.

Further, computer systems and networks have been marked by teachers as important as well, possibly because they find attractive ways to present theory using practical application. Currently and not suprisingly, text processing and spreadsheets are popular topics in IT secondary school curricula. Teachers support these applications and concepts because of possible integration in other subjects like mathematics, physics, and languages.

Learning programming at schools has a long tradition in Lithuania. Programming was undoubtedly the main part of informatics course in the early eighties. When the informatics course was essentially reformed and changed to information technologies, programming became an optional module. Pupils can choose a module of programming (and algorithms) basics in the 9-10th and 11-12th grades. The aim of these modules is to familiarize students with programming constructions, encourage them to choose informatics studies in universities and colleges. While learning these modules, pupils are familiarized with solution methods of simple tasks, data structures, and algorithm modification.

Programming skills hold quite a big part of informatics studies at universities and colleges. The demand for programmers is considerable. Therefore, the need to evaluate the acquired knowledge and skills became a necessity and the national exams in information technology and programming have been carried out since 2006. Pupils, who pass the national exam in programming successfully, have more possibilities to become students of the desired trend of studies, i.e. informatics. At the same time, this is a test whether a student is apt for studying informatics. There are many first-year students who quit their studies since they find programming a hardly understandable and uninviting occupation for themselves.

Despite this deep tradition to teach programming at schools and having a national programming exam (with approximately 800 pupils each year), only 27% of teachers think that programming is very important and about one third consider it important. Teachers' opinion about programming at schools decreased every year. When we interviewed a group of teachers, two main reasons were discovered. First, teaching programming is considered to be boring by students, and so less of them have interest in that. Second, novice teachers do not feel confident enough to teach programming. The first reason is mostly connected with old-fashioned approaches to teach programming (almost no interaction, no good environment and visualization for teaching programming at schools in Lithuania). Deeper problems are due to teachers' education. Less school graduated students like to become teachers. The number of pedagogical students, especially in sciences, mathematics, and informatics decreases every year. In case we would like to improve informatics education in schools, we should keep in mind these severe problems.

Is is difficult to interpret why teachers think that the concept of computer logics is almost not important, Therefore an interview with five informatics teachers was conducted to find the reasons. The interviewed teachers were experienced teachers with about twenty years of teaching experience in informatics. Logics was explicitely taught in Lithuanian schools from 1986 to 2002. It was related with computer logical devices (logical scheme, the laws and expressions of logics, triggers), Boolean algebra and Boolean data type in programming languages. However, these topics were not attractive for pupils. The reason for that has not been researched yet, but it may possibly a too technical representation and lack of appropriate methodology. After changes in the informatics curriculum in 2002, the moduel logics was eliminated and programming became an optional course. Last year, during the recent reform of information technologies curriculum, it was planned to include logics again. There were a lot of discussions on this topic. In the end, more than 50% of informatics teachers did not support this idea. As a result logics has not been included in the new curriculum.

Teachers' response about social and ethical issues of IT can be explained by lack of pupils' interest and methodological material, as well as interesting and attractive assignments for students. Interviews with teachers revealed that this topic is

considered important, but more efforts should be put into its representation to students.

Selecting informatics concepts for secondary schools is a complex process (Fig. 3). We have presented above just a part of this dynamic process in order to find directions.

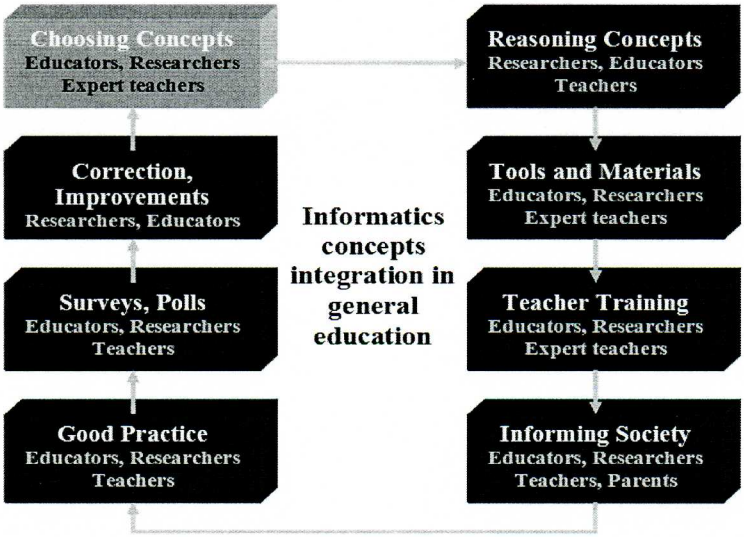

Figure 3. The process of integration of informatics concepts in general education

In general, researchers, educators, collaborating with expert teachers, should reflect and agree on important concepts (Fig. 3). The next necessary steps are

- preparing all the tools and methodological materials for students and teachers,
- organizing teachers' training,
- publishing explanatory materials, and finally
- developing approaches and showing examples and to identify good practice.

Monitoring of this process and research should show whether the selected concepts and prepared materials are suitable. Based on research, surveys and polls, the initial steps should be corrected to improve the process.

CONCLUSION

Information technology and informatics have developed extremely rapidly, particularly in the field of an almost anmanageable offer of (educational) software. Therefore it seems logical and necessary to concentrate on fundamental informatics concepts, particularly in the field of secondary education. Surveys show that the youth have highly developed product-related skills which usually are inadequate to their knowledge and competencies nowadays. A systematic grasp of fundamental concepts of informatics and information technology and their interrelations is essential.

A survey on teachers' opinions about topics of informatics in Lithuanian schools revealed the fact that they support more application aspects of information technologies (such as text processing, spreadsheets) and concepts of information and computer systems. Their favour of teaching applications is possibly due to current IT curricula and a better integration in other subjects. Further reasons can be

identified by lack of appropriate teacher training and methodological materials which could and should present informatics fundamentals in a more attractive way.

The selection of informatics concepts for secondary school education is a complex, dynamic and challenging process which involves multi-players (researchers, educators, teachers, parents, etc.), starting from choosing and reasoning concepts, preparing the necessary (digital) tools and methodological materials, teacher training and informing the society, spreading good practice, measuring, analysing, discussing the results and returning to the initial step with enriched experience and broader views.

We would like to end the paper with a quote from Peter Micheuz: "Without doubt, harmonization has a positive connotation, and is a worthwhile goal in many respects" (Micheuz, 2008, p. 325). Let us try to do that!

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Biography

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