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Reasoning on the Content of Informatics Education for Beginners

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Abstract

The article deals with informatics and/or information technology education for beginners. Since introduction of informatics in schools (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 concepts are key concepts in informatics education. However, which other concepts must be included in a comprehensive informatics curriculum and how to find a balance between theoretical informatics fundamentals and application levels? It is high importance to provide young generation with skills both to use computer technology and to understand them in more profound way. Finding a common informatics concept model would help to achieve a better result in general informatics education on the national and international levels. Results of the survey of Lithuanian informatics teachers' opinions on school informatics topics are presented and discussed here. The article concludes with a proposal to harmonize informatics contents on a transnational level.

Keywords: **informatics concepts, informatics fundamentals, teaching informatics, informatics curriculum, information technology.**

Introduction

Informatics as a school subject was introduced in schools in the early 1980s in many countries over the world. The development of informatics in schools, in particular, is characterized by permanent changes in hardware and software and has some variations from country to country. Didactical approaches and key topics of informatics played a very important role as well.

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. Teaching informatics was introduced in 1986 in all types of secondary schools in Lithuania. As a compulsory or partly compulsory subject it has been delivered in Belarus, Bulgaria, Czech Republic, Latvia, Poland, Romania, Russia, Slovak Republic, Hungary, Germany, and other countries (Sendova, Azalov and Muirhead, 1995; Hawkridge, 1996). The course is changed permanently: at the beginning teaching about computers and training of programming skills used to get more attention, while nowadays we observe a shift to developing of skills of practical use of information and communication technology (ICT) in teaching and learning.

In today's world all the countries pay increasing 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, but not to its applying to the process of learning. In order to emphasize the novelty of the course in informatics and the aspect of its applicability, most of the countries, including Lithuania, have renamed it into information technology (IT).

Lithuania has strong tradition to teach informatics. A group on informatics education research, formed more than thirty years ago at the Institute of Mathematics and Informatics of Vilnius University, is well-known in the world: it conducts research, prepares doctoral students, publishes scientific and methodological papers, books, releases two international journals, participates in international working groups, prepares expertises. The content of the course that has been taught in lower and upper secondary Lithuanian schools as well as the evaluation scheme, and even the name have been changed for several times; nevertheless it has remained as a separate subject (now called 'information technology'). Besides, one of the most important components of IT is to make pupils of comprehensive schools ICT literate and computer native. Today, the information technology course is compulsory for the 5-10th grades of the lower secondary (named basic) school (approximately 1 hour per week, 35 hours per year). There are some optional modules as well (e.g. programming). Students of the upper secondary school (11th and 12th grades) can choose the advanced optional modules of the subject and have to learn the content defined in the course curriculum. During the lessons, an integrative nature of the course is being stressed; pupils are prompt to see parallels with other subjects, to employ modern methods, to differentiate contents, etc.

Concerning the content of informatics or information technology in secondary schools, there is no common international agreement or accepted IT-framework. There have been several discussions (Dagiene and Futschek,

2010; Micheuz, 2008; Hromkovic, 2006; Dagiene, 2006; Micheuz, 2005; Schubert, 2004) on the question: What concepts of informatics and information technologies should be included in general education?

Almost a common opinion is that fundamentals of algorithms and programming are the key concepts in school informatics education. How many such concepts we need for beginners? 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 pupils and ensure productive and sustainable learning? The article discusses these questions, considering formal and informal education.

Research methods, used in this contribution, include analysis of informatics and information technology concepts, based on systematic 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 concepts of informatics

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 and 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 were discussed in the paper (Dagiene and Futschek, 2010).

ACM K–12 curriculum report refers to the idea of information technology fluency of the National Research Council and describes the informatics-concepts as 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. Concepts are understood as the ten basic ideas that underlie modern computers, networks, and information: 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 standard 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 the paper by Pieter 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) to what should be introduced in school from the theory of informatics, and whether it should be introduced at all.

Collaboration in International Informatics and Computer Fluency contest BEBRAS reveals six concepts important for general informatics education (Dagiene and 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.

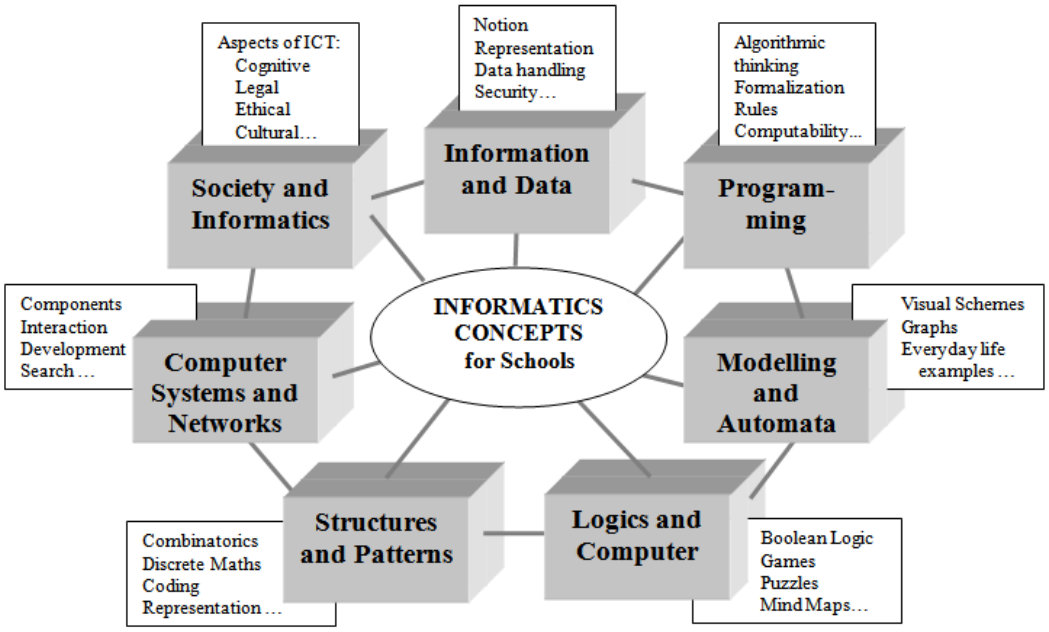

Figure 1. Summarized key informatics concepts for schools

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. The 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. The concept 'information' is also 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. Thus they should be used to express the core scientific concepts.

Basing on the thoughts presented above, 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 (Figure 1).

If we were able to find a clear answer to the question, what fundamentals of informatics and information technology are, it would be easier to develop the taxonomy of concepts, to prepare essential concepts for learning informatics at school and to design a framework of modern informatics and information technology curricula.

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.

The concept of algorithm is fundamental for training in introductory informatics. We can consider the concept of algorithm independently of the software context. Other key issues in connection with the concept of algorithm include the question whether an algorithm holds, whether a problem is decidable, computable, etc. Such questions seem to be too complex for the sphere of secondary education. However, it depends on teachers' qualification to present simple examples that can be formulated intuitively and can be used as introduction of these topics in informatics in secondary schools.

Modelling involves 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 computer 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, 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).

A survey of teachers' opinion was conducted in Lithuania last year in order to know what concepts of informatics and information technologies teachers support most. 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.

Survey of teachers' opinion

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'. Also, there was a possibility to choose the option 'I do not have my opinion' (generally less than 5 percent used this opportunity; therefore we do not include this response 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 (Figure 2).

Interpretation of the plain quantitative data is not an easy task. We have been collaborating with teachers for a long time, thus it is possible to understand their intentions. 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 put into teacher training, a lot of methodological material has been developed, school textbooks include information theory topics and relate them with practical skills. Then it is easy to understand, why the vast majority of the teachers think that the information concept is important or medium important.

Computer systems and networks have been marked by teachers as an important concept possibly because they find attractive ways to present theory using practical application of the topic. Text processing and spreadsheets topics are currently included in the IT secondary school

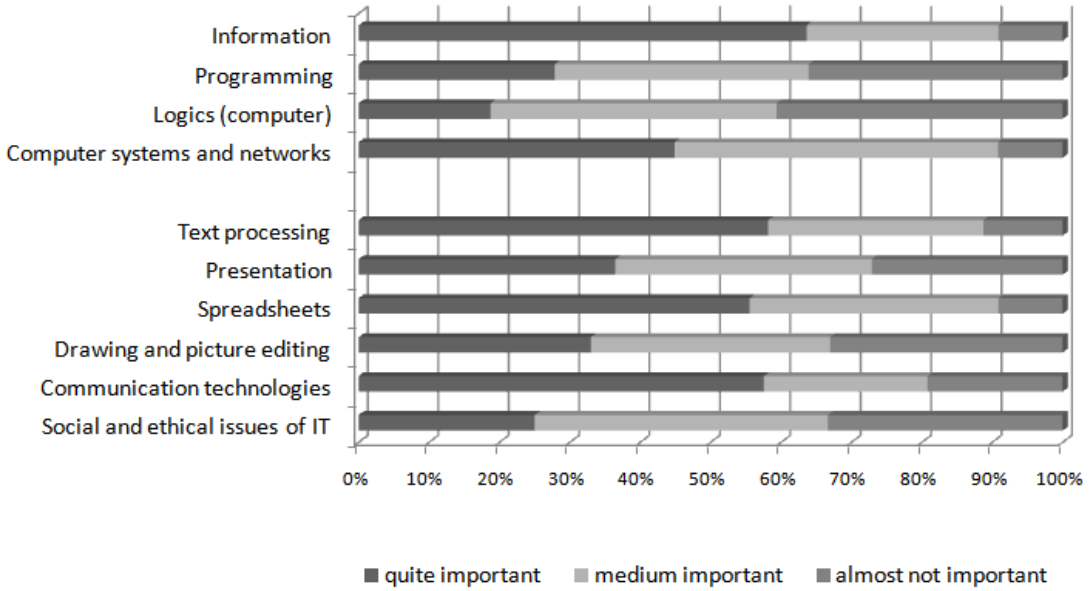

Figure 2. Results of teachers' opinions on the question 'How important do you find the following topics to be taught in schools?'

curricula, and teachers support these concepts because of a broad application domain and possible integration with other subjects like mathematics, physics, and languages.

Learning programming at schools has long traditions in Lithuania. Beyond a doubt, programming was 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 quite many first-year students who quit their studies since they find programming a hardly understandable and uninviting occupation for themselves.

Despite deep traditions to teach programming at schools and having a national programming exam (with approximately 800 pupils each year), only 27 percent of teachers think that programming is quite important and about one third (35 percent) that it is of medium importance. Teachers' opinion as to the learning programming at schools has been decreasing each year. When we interviewed a group of teachers, two main reasons were discovered: first, teaching programming is considered to be boring by students, and ever less and less pupils have interest in that, second, novice teachers feel not strong enough in programming themselves. 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 connected with teacher education: less and less school graduated pupils would like to be teachers; the number of pedagogical students, especially in sciences, mathematics, and informatics decreased each year. In case we would like to improve informatics education in schools, we should keep in mind the problems mentioned.

The logics topic was taught in Lithuanian schools in 1986-2002. 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 (it has not been studied why, but possibly because of too technical representation and lack of methodology). After changes in the informatics curriculum in 2002, the logics module was eliminated and programming became an optional course. Last year, during the recent reform of information technologies curriculum, it was planned to include logics concept again. There were a lot of discussions on this topic; however, more than 50 per cent of informatics teachers did not support this idea. Therefore, the logics concept was not included in the new curriculum of Information technology.

Teachers' response regarding the social and ethical issues of IT can be explained by the lack of interest on the part of pupils and lack of methodological material, as well as interesting and attractive assignments for pupils. The talk (informal) with teachers revealed this topic to be important, but more efforts should be put into its representation to pupils.

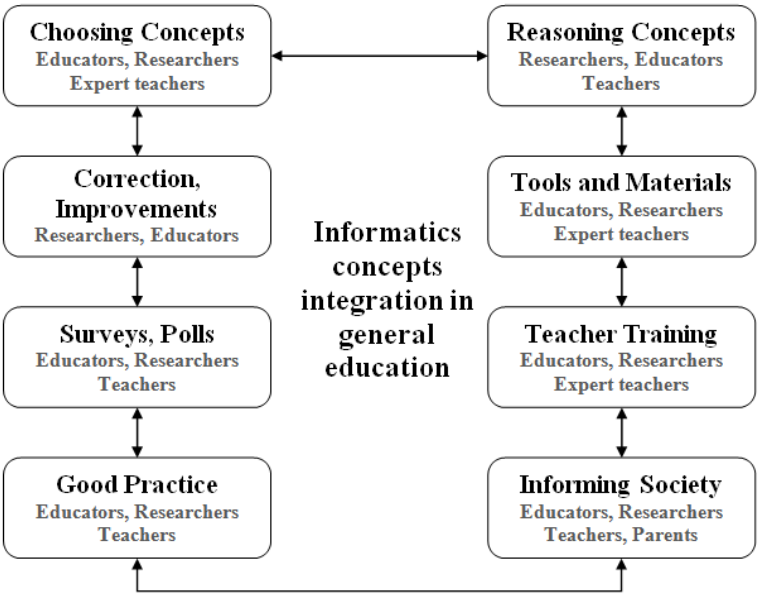

Figure 3. The process of integration of informatics concepts in general education

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 (Figure 3). We have presented above just a part of this dynamic process in order to find directions.

In general, researchers, educators, collaborating with expert teachers, should think over and choose the concepts (Figure 3). The next necessary steps are to prepare all the tools and methodological materials for students and teachers, to organize teacher training, to publish explanatory materials, develop approaches, show examples and to identify good practice.

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

Conclusions

Information technology and informatics has developed extremely rapidly, particularly in the software area, the number of software products and their versions have been growing and changing every day. It thus seems logical and necessary to concentrate on informatics fundamental 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 therefore essential.

The opinion when talking to teachers (informal survey) in Lithuania has shown that they support more application aspects of information technologies (such as text processing, spreadsheets) and concepts of information and computer systems. Their attention to application is possibly caused by the stress on these topics in the previous and current IT curricula, good possibilities of integration with other subjects, as well as the lack of teacher training and methodological material that attractively presents the informatics fundamentals.

Selection of informatics concepts for secondary school education is a complex, dynamic and challenging process. This is a spiral process of actions that involve multi-players (researchers, educators, teachers, parents, etc.), starting from choosing and reasoning concepts, preparing the necessary tools and methodological materials (including digital tools and 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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V. Dagienė, T. Jevsikova

Samprotavimai apie informatikos mokymo turinį pradedantiesiems

Santrauka

Straipsnyje nagrinėjamas informatikos (informacinių technologijų) mokymas pradedantiesiems. Apie informatikos indėlį į bendrąjį ugdymą diskutuojama nuo pat informatikos atsiradimo bendrojo ugdymo mokyklose pradžios (kaip integruoto arba savarankiško mokomojo dalyko), tačiau šis klausimas iki šiol lieka atviras. Daugelis mokslininkų sutinka, kad algoritmai ir programavimas yra esminiai informatikos mokymo konceptai. Mažiau sutarimo esama dėl kitų konceptų, kurie turėtų būti įtraukiami į informatikos bendrąją programą, ir pusiausvyros tarp informatikos teorinių pagrindų ir taikymo lygmenų radimo.

Informatika įvairių šalių mokyklose atsirado 20 a. devintojo dešimtmečio pradžioje. Informatikos mokymo mokykloje vystymuisi darė įtaką nuolatinė programinės įrangos, aparatinės įrangos kaita, šalių tradicijos. Rytų Europos šalys, turinčios akademinio mokymo tradicijas, įvedė informatiką kaip atskirą privalomą arba iš dalies privalomą dalyką (Baltarusija, Bulgarija, Čekija, Latvija, Lenkija, Lietuva, Rumunija, Rusija, Slovakija, Vengrija, Vokietija). Per daugiau kaip 20 metų informatikos mokyme matėsi postūmis nuo programavimo ir kompiuterių sandaros mokymo link informacinių technologijų taikymo. Kai kurios šalys (tarp jų ir Lietuva) net pervadino informatikos dalyką į „informacines technologijas“. Tačiau besimokantieji turėtų įgyti ir kompiuterio naudojimo įgūdžių, ir supratimo, kaip kompiuteris veikia.

Sutarimo dėl informatikos konceptų, kurių reikėtų mokyti pradedančiuosius, tarptautiniu lygiu nėra. Bendras modelis informatikos mokymui galėtų padėti pasiekti geresnių informatikos bendojo ugdymo rezultatų tiek nacionaliniu, tiek tarptautiniu lygiu. Todėl šiame straipsnyje analizuojami ir sisteminami informatikos konceptai, kuriuos reikėtų įtraukti į pradedančiųjų informatikos mokymo programą. Remiamasi mokslinėmis publikacijomis, aprašančiomis įvairių valstybių informatikos mokymo patirtį, oficialiais dokumentais, turima prieš daugiau kaip trisdešimt metų susiformavusios informatikos mokymo tyrėjų grupės, esančios Matematikos ir informatikos institute (Vilniaus universitetas) tyrimų patirtimi. Analizuojamos tokios tarptautinės informatikos mokymo programos kaip UNESCO/IFIP, ACM K-12, Vokietijos programa „The German Society for Informatics GI“, Austrijos mokymo programa, tarptautinių informacinių technologijų konkursų konceptai ir kt. Apibendrinant tarptautiniuose šaltiniuose rekomenduojamus konceptus ir temas, siūloma į informatikos turinį pradedantiesiems įtraukti tokias pagrindines 7 temas (konceptus), kaip 1) informacija ir duomenys, 2) programavimas, 3) modeliavimas ir baigtiniai automatai, 4) kompiuterinė logika, 5) struktūros ir šablonai, 6) kompiuterių sistemos ir tinklai, 7) visuomenė ir informatika.

Pateikiami ir aptariami Lietuvos mokytojų nuomonių apie informatikos mokymo mokykloje temas tyrimo rezultatai. Tyrime dalyvavo 115 respondentų iš visos šalies – informacinių technologijų mokytojai, dirbantys su 5–12 klasių mokinais. Iš mokytojų nuomonių paaiškėjo, kad svarbiausiomis informacinių technologijų dalyko temomis mokyklose jie laiko informaciją ir duomenis, tekstų apdorojimą, duomenų apdorojimą skaičiuokle, komunikacines technologijas, kompiuterių tinklus ir sistemas. Nepaisant to, kad Lietuvoje turime stiprias programavimo mokymo tradicijas, tik 27% mokytojų mano, kad ši informatikos mokymo sritis yra svarbi, ir 35% mano, kad ši sritis yra vidutiniškai svarbi. Tai gali būti paaiškinta tuo, kad, viena vertus, programavimas mokiniams atrodo sudėtingas ir nuobodus, o, kita vertus, patys mokytojai nesijaučia stiprūs programavime (dėl anksčiau minėtos tendencijos informatikos mokyme labiau kreipti dėmesį į informacinių technologijų taikymo aspektus, dominavusios paskutinį dešimtmetį). Pastebėta, kad mokytojų atsakymuose atsispindi dabartinės informatikos mokymo programos ir turimos metodinės medžiagos konkrečioms temoms įtaka.

Siūloma informatikos mokymo turinio harmonizavimo transnacionaliniu lygiu schema. Tai spiralinis procesas, kurio metu tyrėjai, švietimo specialistai, bendradabiaudami su patyrusiais mokytojais, turėtų apgalvoti ir pasirinkti svarbius informatikos konceptus (temas). Tolesni žingsniai – parengti priemones ir metodinę medžiaga mokytojams ir besimokantiesiems, sukurti pavyzdžius, apmokyti mokytojus, identifikuoti gerąją patirtį. Stebėsenos ir tyrimų procesai turėtų parodyti, ar pasirinkti konceptai (temos) ir parengtos priemonės pasiteisina. Remiantis tyrimų rezultatais, pradiniai žingsniai koreguojami siekiant patobulinti visą procesą.

Reikšminiai žodžiai: informatikos apibrėžtis, informatikos pagrindai, informatikos mokymas, informatikos ugdymo turinys, informacinės technologijos.

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