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Computer Science Education on High Schools

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Abstract. The contribution discusses the situation of computer science (CS) education on high school level (secondary education). At first some order in terms needs to be made so we can distinguish different meanings hidden in "informatics on high school". Then the current situation of CS education in Czech Republic is discussed. The most important recent phenomenon influencing our high schools is the curricular reform. The fundamental changes of view are introduced briefly, however our main aim is to discuss ICT and CS related education in the new setup. In the second part of the contribution a few foreign countries are picked and their inspiring approach to CS in high schools is described, headed by Israel.

Introduction

This paper examines computer science (CS) education on high schools from the curricular point of view. High schools are meant in the sense of secondary education, we could also say it is the final stage of K-12. CS is a young field, yet important. It is being introduced to high schools broadly last years – however, only rarely as a single subject. That is why we must search also in various informatics, ICT or programming courses syllabi.

Our main concern is the situation in Czech Republic, where the CS related terminology is often confused and therefore misunderstood. A universal term *informatics* is used in many different meanings. In educational context it stands most frequently for computer literacy, simply said "using computers", or information literacy, simply "using information". It can as well refer to use of computers (or other IT) while educating other subjects, or simply to the school IT infrastructure, anyhow it is used. More rare is the meaning of teaching programming and even more rare the meaning of computer science. This ambiguity impedes not only our research, but also the development of any computer related education in Czech Republic.

In education, also the term computer science itself bears various meanings in the world. It can be seen clearly in the syllabi of basic CS courses on universities. In some cases, such a course reduces to programming in a specific languge. On the other side we could also find much more theoretical approaches, including Turing machines and computability. To avoid a possible reader's confusion, we will explain now what do we mean by CS for our purposes, i. e., its education on high schools. It is obvious that the idea of teching CS in all its width is for many reasons unrealistic. An adequate subset has to be chosen. In our research, we decided for information, algorithm and efficiency to be the basic concepts of CS for high school level. We search for any traces of these in existing high school curricula, inland or abroad.

We should also make clear explicitly that we do not consider programming (coding) of any crucial importance for our purposes, as well as any usage of physical computer at all. They may help significantly of course, but they are not the point of CS education, as we see it in our research. The main reason is the initial difficulty of acquiring sufficient coding skills. That is why we would like to find ways to teach principles of CS without the need of programming. Further details are beyond the scope of this paper.

In the main section of this paper we discuss the situation of CS education on high schools in Czech Republic. At first the curricular reform has to be introduced briefly. It is a recent phenomenon in our school system, influencing heavily the life on kindergartens, grammar schools, high schools, and all others on equal levels. Apart from other modifications, the curricular reform changes the goals of education and updates the content, with respect to current and hopefully also future demands of the labor market.

With an idea of complex changes happening on high schools, we may follow to analyze the new high school programme, aiming to find traces of CS. We will examine the area of Informatics and ICT as the most promising part, then check other areas for possible connections with CS and finally look into key competences, a quite new concept in Czech curricula.

The last few paragraphs of this section deal with recent development. We chose to represent it by describing the ICT Panel. It is an expert group to improve the ICT part of our curricula, and therefore heavily influencing education of CS. Another point of view on the current approach to CS is to examine the shape of school leaving exams, as they are planned freshly for the next few years.

The second section describes briefly some examples of CS education in foreign countries. Most inspiring is the situation in Israel. The other picked are Netherlands and USA.

Situation in Czech Republic

Curricular reform

The most influencing phenomenon on Czech high schools these days is the curricular reform. The former curriculum has been disassembled and put back together into a qualitatively different new system [*VÚP*, 2007]. We will focus on two characteristic changes, introduced by the reform. The first is the two level system of educational programmes, the second the concept of key competences.

Instead of following the former uniform programme, nowadays each school has to create its own unique school programme based on the National framing programme. The main advantage of this approach is exceptional autonomy and freedom. The school programme may reflect for example local specifics, or reorganize the subject structure completely – the only limitation is that the outcomes defined in the National framing programme must be fulfilled. The dark side of school programmes creation is a massive load of formal paperwork hindering teachers in their real work.

Key competences constitute the major goal shift we are experiencing. Teachers task is not to provide knowledge anymore, they are to help students to develop their key competences. The intuitive meaning will suffice here, the reader can get an idea from the following enumeration: Student in general has to be able to solve problems, to communicate, to study, to live with himself and with others, to be a good citizen and a good businessman. These are the six key competences introduced in the National framing programme [*VÚP*, 2007]. Any educational activity should develop one or more of these competences, and besides accomplish other objectives, like train summing fractions. Among the negatives is the abstractness of the concept of key competences. It leads to difficulties, e. g. in correct understanding by teachers or in evaluating progress of their development.

This approach is consistent with a frequent stance that we are teaching fraction operations not only for the sake of them, but primarily for the students can somehow become "better humans" (perhaps more math literate in this case). We may view the concept of key competences as an attempt to formalize this idea of "better human".

Computer science in the new programme

In this subsection we examine possibilities to teach CS provided in the National framing programme.

Informatics and ICT. The most obvious part to look into is the Informatics and ICT educational area (*educational area* is a term corresponding roughly to former *school subject*). The aim of this area is to achieve a certain level of "information literacy", though it is understood as a capability to use digital technology. According to the given description, we could say the area is actually about computer literacy [*VÚP*, 2007].

Luckily, in the detailed characteristic of the area and in the list of content and expected outcomes we find dealing with information mentioned several times. This includes searching for information, evaluating the source quality, obtaining the information, evaluating its quality, relevance, and reliability, measuring it, processing, storing and transfering it. According to the brief specification we gave in the introduction (information, algorithm, efficiency), we count most of this into CS on high schools.

More importantly for our goal, we find also mentions of some sciences. The terminology is unclear again, leaving the reader in doubt. Teachers shall work with informatics as a science, information science, computer science, theoretic informatics and applied informatics. Our translation here is most likely imperfect, though it still illustrates the point on unclear terminology sufficiently.

Looking into concrete content details, the strongest connections to CS are sections about data and information, algorithms and introduction to programming. One of the expected outcomes is that students should apply algorithmic approach to solve problems. Although all this is of marginal importance in context of the whole programme, it is important to remark that all this is considered compulsory for every student.

Other areas. If we look into other educational areas, we will find some possible connections with CS. They can be sources of applications and examples in CS education, or opportunities to mention the CS point of view while educating other areas. This may be important, because there is no time assigned specifically for CS education. Here we mention some of the connections we have found.

At first we can obviously use very much of mathematics, including combinatorics for example. Another possibility is hidden in language areas, where an introduction to linguistic is to be taught, calling for comparison with formal approaches to languages in CS. In biology we have nucleic acids and genetics, that is storing and processing information. A completely different (seemingly far from text-based) view on recording information is provided by cartography. Another area dealing with processing information is learning itself (also included in the programme) and psychology. We can also find the basics of law, which we can see as a set of rules to follow (provided with meta-rules of following itself). The last possible connection with CS we mention is the area of first aid and surviving emergency states. Efficient work with information and algorithmic approach are literally life saving here.

Key competences. As we have implied earlier, key competences represent a much more general category than any educational area. Still, we may examine correspondences with principles lying under CS. That is why we state here that CS may be prove itself as a promising instrument to develop key competences, especially the first three of them (problem solving, communication, learning). From a certain point of view from which CS just is about efficient solving problems and transmitting, storing and using information. That could be the first three key competences in other words.

Recent development

There is an expert group to improve the Informatics and ICT area in the National framing programme, called ICT panel [*Růžičková*, 2010]. They work since 2008 and are supposed to publish their results periodically. Although it is still rather conceptual and theoretic work, there is a promising direction developing: The idea of separating computer usage and computer science has been mentioned repeatedly by both ICT panel members and other researchers and teachers [*Neumajer*, 2009].

A newer document than the programme is the Catalogue of requirements for the school leaving exams [*CERMAT*, 2010]. It corresponds with the programme, but is more specific. We can find more traces of CS. The examinee is required to develop a simple algorithm. Unfortunately, the simplicity is not specified. We may only guess, based on the sample test: It presents, among other tasks, work with an algorithm to find a maximum in a list of natural numbers.

The examinee should also understand the principles of binary coding, data compression, basics of information theory (including Shannon's theorem), use basic programming structures or explain object oriented programming. However, all this is a small portion compared to the rest of the requirements, the emphasis lays fully on computer literacy.

Situation abroad

In this section we briefly mention a few foreign countries, which provide useful experience for us. One of the most interesting is Israel, whose approach is described in an individual subsection. Further inspiration can be found for example in curricular publications of Slovakia, Poland, Hungary, Russia or New Zealand. And again, we have to look into informatics and other syllabi to find something about computer science education.

The first country to mention is Netherlands [*Mašek*, 2009]. They have already a more than ten years long experience with teaching informatics (not CS specifically). Their concept focuses on usability in life, work and business, but not in the limited sense of computer literacy. They teach also a lot of humane aspects (eg. the role of information, technology etc. in society). Traces of CS are scattered all over the programme. However, we could find a few chapters more related to CS. The interesting thing is that the key concept in Netherlands is not algorithm or anything closely similar. They have chosen rather data modelling and managing databases (including relational databases).

Among the recent questions in Netherlands are instituting a unified state exam, the amount and difficulty of advanced content (Java programming, data modelling), and the extent of compulsory minimum (if any) for every student (the module is currently optional).

The situation in USA is much more complex because of multiple levels of directing curricula (national, state, school). However, Computer Science Teachers Association works on developing and introducing unified model programme for primary and secondary education [*Tucker*, 2006]. Although the title of the programme implies it would be about pure CS, their concept is this: "Computer science (CS) is the study of computers and algorithmic processes, including their principles, their hardware and software designs, their applications, and their impact on society". Therefore CS education according to this model programme includes also training in use of digital technologies and teaching general informatics.

At first sight we could say the discussed conception to be roughly the same as that of Czech National framing programme - user skills and informatics (including CS) bond into one subject. However, the American programme is significantly both wider and deeper in the scientific parts. While in the Czech programme CS is of marginal importance (compared to development of computer literacy), in the American programme the basic user skills are to provide solid background for the core of the subject, which is science and technology. CS itself is represented mainly by algorithmics and programming, allowing students to take part on advanced courses or studying CS on university.

There is also a newer purely CS programme for high schools, called Exploring Computer Science Curriculum [*Goode, Chapman*, 2009]. It provides support for six instructional units: Human Computer Interaction, Problem Solving, Web Design, Introduction to Programming, Robotics and Computing Applications. However, not all these units are considered to belong into high school CS course for our research. We are interested mainly in Problem Solving, and partially Introduction to Programming, Robotics and some subtopics in Computing Applications.

Situation in Israel

One of the most daring and old programme we found is in Israel. It was approved in 1990 as a part of a complete project, including piloting the new curriculum, educating teachers and writing textbooks. The aim of the programme is to introduce CS to students as a science. Computer literacy is expected from grammar school (so it is in Czech Republic,at least officially

[*VÚP*, 2007]). The system of CS teaching in Israel is modular, one module takes a semester to study. The introductory module is compulsory for every student [*Gal-Ezer et al.*, 1995]. The other modules shall prepare interested students for their university studies,

Algorithm is the keyword of the programme, as it is being considered the best representative of CS for high school students. Closely related is the notion of complexity. This is the main subject of the basic module. In further lessons students get to know recursion, the whole range of automata (as language acceptors, from finite machines to Turing machines), non-determinism, computer graphics, logic programming, graph theory and many others.

All these are of course included only in advanced modules. The classic formal approach is not used here, an intuitive level of understanding is considered sufficient on high school level.

In the rest of this section we describe a few principles in the background of Israeli curricula. The first states the importance of CS. CS shall be equal to other sciences, like chemistry or physics. This helps to decide about how to set the difficulty of CS.

In CS education, concepts and principles are the primary target, not recent technologies. Programming is taught only to the necessary level for algorithm notation, the goal is not the ability to write code itself. CS education shall consist of conceptual, theoretical work as well as of experimental activities performed on actual computers. Each student shall have his own personal experience with implementing all the theoretical CS concepts. The last principle we will mention is the inclusion of second paradigm. At first, students are educated to think algorithmically using a procedural language. Later they have to get familiar with also a different one - logical, functional, parallel, system or object oriented.

Object oriented programming is a subject of current work in progress. They plan to replace the classic procedural approach with OOP in the introductory module.

Conclusion

In this paper we have examined the possibilities for CS education on high schools in Czech Republic based on the National framing programme and in the context of curricular reform. In the second section we have described some foreign examples of CS education.

It has been shown that CS has no full and direct support in Czech high school curricula. However, with a closer look, many connections can be shown, and particularly the key competences provide a strong base for considering to teach CS. Such possibility is powered by the necessity of developing unique school programmes.

The main drawback we see in the current concept is that it mixes together basic computer usage skills with basics of information and computer science. This results into an incoherent subject, difficult to teach and unpleasant to learn, as its nature is so ambiguous. Compared to this, the confusion in terms is rather a minor hitch. Fortunately, we witness a development of the idea to explicitly separate the user part and the science part. It would, among other advantages, help to clarify what to expect from each course and prevent students from choosing something they don't really want to study.

We have also shown there is lot of foreign experience available. It is inspiring on a conceptual level as well as on the level of educational content and methods. Even the sole knowledge about that students actually are able to cope with sciences, which are usually considered as difficult, is very valuable. Portability of these experiences is of course limited proportionally to differences in foreign school systems.

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