Algorithm development and programming at elementary education in the Czech Republic

P. Hanzalova and S. Hubalovsky

***Abstract*—**The paper deals with algorithm development and programming at elementary schools in the Czech Republic. First, it describes the teaching of information and communication technology in this type of school, according to national curricula. Lists the topics to be discussed and how many of them are directly or partially concerns to algorithms. Furthermore submit proposals for the development of algorithmic thinking, which is important for understanding of computers functionality but mainly programming functionality. The paper shows specific examples that demonstrate easy way for implementation of algorithms into education without explanation the principles of algorithms. Emphasis on principles of constructivist teaching, creativity and key competencies of pupils.

***Keywords*—**Algorithmic thinking, algorithm development, education, historical encryption, programming.

I. Introduction

IN 2013, many Czech elementary schools conducted international survey ICILS of strengths and weaknesses of Czech pupils in the computer and information literacy [1]. In this testing, the Czech Republic ranked the first place (between 19 European countries). Specified themes (aspects) were as follows: Using computers as such; Gathering information and assessing them; Treatment of information; Transformation of information; Creating of information; Secure of information, Sharing and use of information [1]. If we focus on these topics, we find that there is no mention on algorithms, algorithmic thinking. Therefore, we find out whether the algorithmic thinking, algorithms, or even programming itself is part of basic education in the Czech Republic. Some foreign sources (e.g. [2]) states that Czech Republic belongs among the countries where algorithmic thinking is not a part of learning content. Even the actual evaluation of above mentioned research notes in its conclusion: "*These areas are not only ones that would be worth more supported. Between teachers, for example, are increasingly talking about the development of the so-called computational thinking as a worthy and useful part of the curriculum.*" If we focus on the definition of computational thinking in ISTE [3], we find that they largely mention algorithmic thinking.

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II. Informatics at Elementary Schools in the Czech Republic

A. Educational Documents

Schools in the Czech Republic provide education by the so-called School educational programs. Each school has its own program, created directly by teachers of the school. They may therefore vary, but the basic structure and minimum requirements based on the national curricula - Framework educational programs. Generally, there are several training programs – one for each type of school. Here we find the mandatory educational areas, their contents and expected outcomes (defined abilities and skills that student after completing the course should know). Emphasis is on the core competencies of pupil ('*These are complexes of knowledge, skills, and attitudes That enable successful task performance and problem solving with Respect to real-world sustainability problems, challenges, and Opportunities*" [4]) and on cross-cutting themes (topics of current problems of the contemporary world [5]). School education program can updated every year to accommodate it as much as possible.

Framework educational program is main document responsible for educational goals in the Czech Republic. Framework educational program [5] sets out following objectives of the elementary education. They are applicable to all educational areas:

- enable pupils to master learning strategies and motivate them for lifelong learning;
- encourage pupils to creative thinking, logical reasoning and problem solving;
- encourage pupils to versatile, effective and open communication;
- developing pupils ability to cooperate and respect the work and successes of themselves and others;
- preparing pupils to behave as independent, free and responsible personalities, asserting their rights and fulfilling their obligations;
- creating pupils needs to express positive feelings in their manners, behavior, and living through life situations; develop their responsiveness and sensitive relationships with people, environment and nature;

- teach pupils to actively develop and protect their physical, mental and social health and be responsible for it;
- encouraging pupils to tolerance and respect for other people, their cultures and spiritual values, and teach them to live together with other people;
- help students discover and develop their own capacities in accordance with real possibilities and to apply these together with knowledge and skills in decision making about their own life and career orientation.

B. Information and Communication Technologies

There are nine educational areas in Framework educational program FEP [5]. One of them is related directly to informatics - Information and Communication Technology. Subject based of this area is required on both the first and the second grade of elementary school. Its hour's donation is at least one hour per week for the first five years and again at least one hour per week in the next four years. Pupils should therefore have at least two hours per week of ICT in all primary school. It is a very small amount. Most of schools increased it two hours higher elementary schools.

Education of informatics has the following content:

- Computer Basics;
- Finding the information and communication;
- Development and use of information;

The main goal of the first grade of elementary school is to operate with computer and be able to easily find information and use basic functions of text and image editor and use simple means of communication. At the second stage the pupil would should be able to evaluate the credibility of information, to manage the copyright and use different editors considering typography and aesthetics.

However, we discover how many pupils are engaged in algorithmic development and programming. Among the objectives of this educational area we find the following, which are at least partly related to our topic:

- the ability to formulate a request and use algorithmic thinking when interacting with a computer;
- understand the function of computer technology as a means of simulation and modeling of natural and social phenomena and processes.

C. Programming at Primary Education

The programming is not part of the curriculum at elementary schools. During the classic mandatory hours some teachers mention the theory of algorithm development, but that is not the norm. Some schools may be exception. Programming may be taught as an optional subject (leisure activities) outside the schedule. They teach programming based on children's programming languages (e.g. Scratch, Baltika, Imagine Logo, etc.). They have set native language of pupils and thereby eliminates the language barrier and simplifies the work of pupils. Some primary schools have programmable kits (robots) – e.g. Lego Mindstorms, Mercury, Fischertechnik, Arduino or other alternatives [6].

III. Algorithm Development based on Encryption

„Written algorithms are often too abstract for beginners to be understood. The students have to understand the syntax of the language that describes algorithms and also the idea how the algorithm solves the problem.“ [7]

That's why we decided to develop algorithmic thinking, which is not directly related to the programming language at elementary school. Thus, we learn how to think algorithmically, how to create algorithms, how to understand and how to verify that algorithm works correctly. Above mentioned is based on the basic skills of algorithmic thinking by G. Futschek [8].

Encryption was chosen deliberately. From the experience of workshops and lectures we know that the ciphers are for pupils something mysterious that they would like to clarify. They are interested in their history and their technique. The first reason is therefore due to motivation. The historic encryption systems are easy to understand. The cipher are appropriate for development of algorithmic thinking because there is a need to follow the exact procedure [9]. In addition, there are many different codes that can be sorted based on their difficulty. Therefore, it is possible to use the cipher for development of algorithmic thinking at the first and second stage of elementary high school. The advantage is also that encryption contributed to the development of information and communications technologies - the subject of informatics the encryption historically sets.

IV. Case Study – Trithemius Cipher

A. Goals of the Project

The main goal is to convince the teachers that algorithm development can be included to ICT lessons by funny form. Other goal is support teachers and show them that algorithm development is beneficial for pupils and at the same time it fulfills many other demands of school curricula and modern trends in schools. The most of the objectives and key competencies of FEP we have therefore included to our education of algorithm development. We try to observe the principles of constructivism, like Futschek and Moschitz who develops algorithmic thinking and playing by inventing algorithms [7].

The following goals was set within the education:

- To familiarize students with algorithmic structures;
- To develop pupils' key skills (problem solving, communication,);
- To acquaint students with the principles of the solution of "programming tasks";
- To familiarize students with the method of verifying the correctness of the algorithm;
- To cooperative process solution of the problem with respect to the aesthetic aspect;

- To develop pupils creativity;
- Use text, spreadsheet or graphics editor processing results.

Figure 1 shows the principle (cycle) of functionality of the exercise. We can see that this is a classic example of the structure of decision-making. The teacher intervenes only at the beginning and end of the process, unless otherwise necessary. The cycle of the task solution the pupils passes in groups. They respet the requirements of the assignment, where the individual steps are briefly but clearly described.

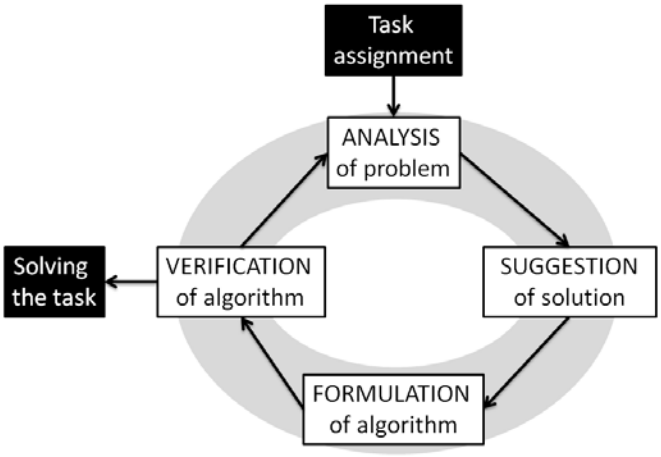

Fig. 1 Scheme of task solution

B. Task the Assignment

The pupils are split into groups of two or three pupils. They read the assignment and divide the work (who will seek out sources of information sources who will sort the information, process, graphically edit, etc.).

Pupils are first introduced to the particular type of cipher, e.g. Trithemius cipher (first Polyalphabetic cipher with password). They seek information about cipher history and discover how encrypts and decrypts by themselves.

Then the pupils verifies whether they understand the principle of the cipher by first task – they have to checked a number of different programs by method trial / error and identify which program can be used for encryption of the cipher text.

The main task is describe the principle of encryption using encryption tools. In Figure 2 there is shown template for the production of Alberti cipher disk. The cipher disk significantly accelerates encryption and decryption of text without using a computer. Pupils has to describe the algorithm of encryption of Trithemius cipher using pencil and paper and Alberti's cipher disk so according to their instructions. They have to prepare "final report" of solution, which describe how they proceed and what they use. They are evaluated based on the final report.

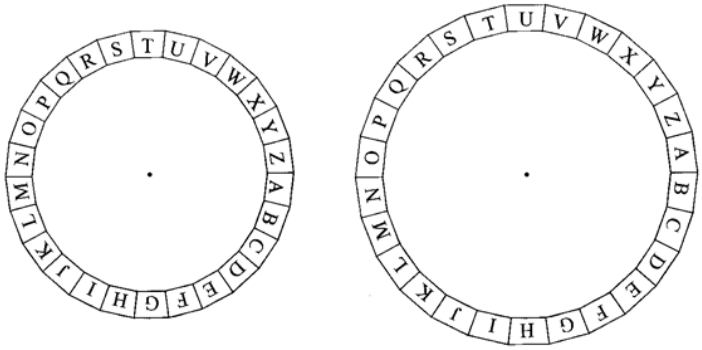

Fig. 2 Template for creating of Alberti cipher disc

C. Analysis of the Problem

The analysis briefly describes the history of Trithemius ciphers and differences between monoalfabetical and polyalfabetical substitution encryption. Pupils receive information from Internet sources, which subsequently put into the final report. Pupils are also taught that they should always indicate the sources of information from which the draw and should not "copied verbatim" or only to a limited extent and clearly marked. The pupils receive information on copyright and information ethics, which is also mandatory educational content.

D. Suggestion of Solution

This section contains proposal for procedure for encryption. Pupils thus develop their algorithmic thinking. They have to describe the algorithm of encryption unambiguously - from the experience they simply derive the properties of the algorithm:

- Finiteness - the user should encrypt whole message and then terminate job;
- Universality - procedure should apply for a language other than Czech, for a different alphabet (if the modified disk encryption)
- Determination - each step can only be done one way (e.g. turn disk by one position" does not meet this feature because we do not know exactly which direction);
- Resultativness - output will be encrypted text;
- Elementariness - the whole procedure consists of a finite number of simple steps.

E. Formulation of Algorithm

Initially, the pupils describe the solution by sentences. Subsequently, they try to simplify the process as much as possible, or to supplement scheme or pictures (see Fig. 3).

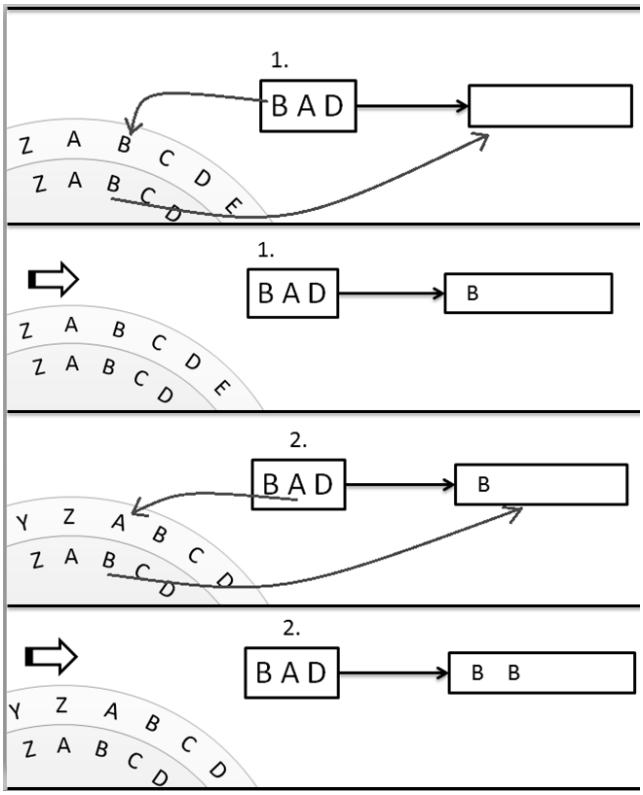

Fig. 3 Scheme of Trithemius cipher

F. Verification of Algorithm

The verification is one of the most important and also the most difficult part of the whole task. The pupils have to take the role of a computer that does not know anything about a given task and solution. They are managed by specified commands. They have to realize if there is only one variant of solution (then the algorithm is written correctly), or whether there are more solutions.

The teacher can recommend the pupils the way of algorithm evaluation. It is so called "algorithm replay". One student reads slowly commands and others are trying to perform the commands accurately. If they are not something bright, it must ask. It is necessary to observe and discuss whether there is error in the formulation of process and how to fix it.

If such an error is found, pupils have to find out where the problem is and the whole cycle of solution repeats, but with a different problem. If no such errors exists, the entire solution can be delivered to teacher.

G. Solving the Task and Discussion

The solutions is handed over in form of document that contains all the parts mentioned above. Because in one class is always more groups of pupils, the teacher will have to evaluate several such documents after the completion, but also can work with them further. As already mentioned, from the developed processes can be easily inferred all five properties of algorithm. The pupils can discuss whether everyone succeeded at the first attempt to meet all the properties. If not, what was the problem and how to suggested solutions.

In addition, it can be discussed how to write algorithms. The various steps of the algorithm can be analyzed and suggest basic instructions (inputs, outputs, conditions, cycles). Subsequently, pupils can be acquainted with flowcharts.

V. Conclusion

Although algorithm development and programming are not mandatory part of the education at elementary school of the Czech Republic, it would not be problem within hours of information and communication technologies more effective support algorithmic thinking of pupils. It is true that pupils can control basic application such as text, tabular and graphical editors, but the algorithm development is often neglected. It also pointed to recent studies [1], [10].

„Instead of children bored out of their minds being taught how to use Word or Excel by bored teachers, we could have 11-year-olds able to write simple 2D computer animations." [10]

Algorithmic thinking is very important not only for understanding the operation of the computer. Is needed in many other fields, especially science, e.g. mathematics includes a lot of of different algorithms, within lessons of chemistry and physics is a need to respect precise algorithms for experiments. For some pupils it is difficult to orient in the algorithms. The algorithmic thinking should be supported in different lessons, not only in teaching of programming. The paper presents one examples of development of algorithmic thinking.

Acknowledgment

This research has been supported by: Specific research project of University of Hradec Kralove, Faculty of Education in 2015 No. 2144 and Specific research project of University of Hradec Kralove, Faculty of Science in 2015 No. 2108.

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