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## Alternative Methods of Teaching Algorithms

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### Abstract

Nowadays, algorithmic thinking is considered to be one of the key competences of students from primary to higher education. In our paper we point out the possibility of alternative methods of teaching algorithms. We deal with the concept of algorithm, problem analysis and algorithmic thinking. We search for such tasks that motivate and mobilize students to seek the essence of the task first impression of which is mystique. They raise the curiosity and desire to uncover the mystery as they are based on the principle of black box. Particular topics are same in Mathematics as well as in Computer Science which enables the usage of cross-curricular activities. We focus on numerical sequences, codes, ciphers, algebraic riddles and puzzles based on the principle of positional systems. In the paper, we present the tasks that can be programmed, but it is also important to know the basic, often very simple, mathematic relations. The mentioned tasks were presented mainly within various teacher trainings and educational workshops where they provoked a very positive response and managed to activate the teachers themselves.

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### 1. Introduction

The development of algorithmic and problem thinking is very important not only for the school environment, but also for a large number of activities in real life. In the paper, we try to point out the possibilities of implementation of alternative means in teaching algorithmization in Informatics and also Mathematics. Contextually Mathematics and Informatics intersect mostly in the term of algorithm, which can be defined as a kind of instructions designed to solve a particular problem. Many students nowadays consider Mathematics useless. It is therefore necessary to focus on such tasks that activate their activity and motivate them towards searching for the essence of the activity, which is of a mystique nature. It evokes curiosity in the students, together with a desire to solve the mystery. In the paper, we will present tasks that can be programmed and in which it is important to know the basic, often very simple, mathematic relations.

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## 2. Activating Teaching Methods

Activating methods are procedures leading the teaching towards achieving the educational goals, in particular based on one's own work (Guniš et al. 2009). Activating teaching methods do not usually require raising financial resources, ensuring special teaching aids, technologies, nor creating or building special classrooms (Sirotová, 2011). We can activate student's activity even by a simple change of the concept of lessons, for example by regular tasks, the solving of which will be rewarded by extra points for the final evaluation (Vilonen, 2008). There is a variety of activation methods (Guniš et al. 2009), we will, however, focus mostly on problem solving methods – in particular the black box method.

### 2.1. The Black Box Method

The Problem of the Black Box in electrical engineering was first used in 1956 by Ashby. According to him, the engineer is given a sealed box that has terminal for inputs, to which he may bring any voltages, shocks, or other disturbances he pleases, and terminals for output, from which he may observe what he can. He is to deduce what he can of its contents (Ashby 1956). In general, The Black Box is a substantial system (object, process, phenomenon) with internal organization, structure and element behavior, about which the observer has no information, but has the option of impacting the whole system via its inputs and register its reactions via its outputs. The observation of the black box is therefore behavioral. The observer affects the black box via its input and gets information from its output (Figure 1). In this way, the observer and the black box create a system with feedback (Cápá and Magdin 2011).

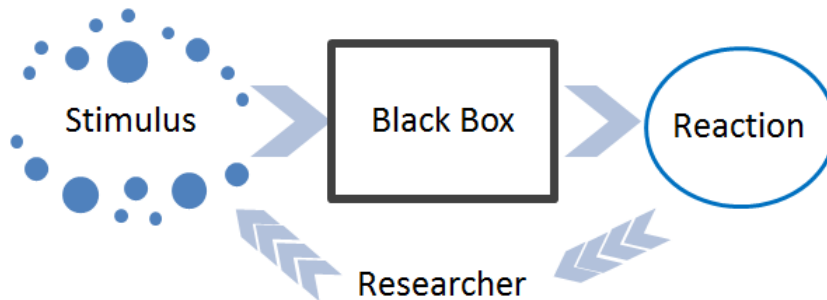


Figure 1. Scheme of the method of black box principle.

MS Excel could be used also as a kind of Black Box. Its calculations can be seen as "program outputs of hidden programs". By drawing the curtain away from the hidden processes, one can illustrate concepts and properties that are typical for all programs (Lovászová and Hvorecký, 2005). Gal-Ezer (2004) use the new approach advocates integrating three-part questions which ask not only to identify the algorithmic problem that a given algorithm solves and to analyze its complexity, but also to design a new algorithm that performs the same task. We search for such tasks that motivate and mobilize students to seek the essence of the task first impression of which is mystique. Concept of magic applications presented an interesting task which resembled the magic could be based on the principle of the Black Box – the Black Box Method (BBM).

How to execute the BBM in educational practice? At the beginning of the experiment there are no assumptions of the black box operation. The student works with an application which is acting mysteriously, for example reading their mind. Of course, the student immediately thinks that the whole program works on basis of some kind of hidden principle (algorithm) they just do not know what it is yet, so the application is a kind of mystery to the user. Only a mechanism (instructions) is available, showing ways of interacting with the box (inputs). This way they can experiment with the application, explore its reactions (outputs) to different inputs, trying to solve this "mystery" (Figure 1). Students' aim is to observe the interaction between inputs and outputs and to make a protocol about their observations, which will be the basis for the formulation of the algorithm operating the box. (Cápá et. al. 2001b)

### 3. Tasks Suitable for the Black Box Method Implementation

There are a number of tasks which, on one hand, meet the condition of mathematical essence of the problem solution (Cápaj and Magdin, 2011); on the other hand, they are not suitable for the black box method, while they do not include programming relevant algorithm. It is therefore not possible to create a functional application that would act as the black box for the experimentation. We suggest the following types of tasks, which are listed according to the difficulty level of their solving. The presented principles can be transformed into computer applications. Tangible black boxes can be then substituted by electronic model. In all of the mentioned examples, it is then presumed that the student (experimenter) has access to functional magical applications.

#### 3.1. Linear Dependence

It focuses on a search for linear dependence based on manipulation with the application. It is necessary to define a formula or verbally render a rule, based on which the input transforms itself into output (Figure 2).

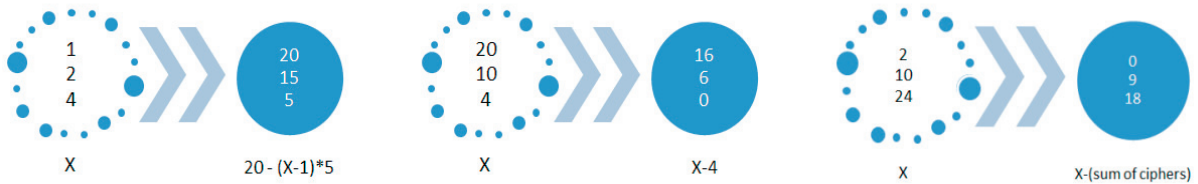


Figure 2. Linear dependence tasks – Define a formula

#### 3.2. Work with Text Strings

The black box designed to exercise the work with text strings is suitable for exercising the ciphering algorithms. Ciphering is a transformation of information from one form into another with the purpose of hiding the real content of the information from the eyes of unwanted persons. For exercises related to ciphering to be used in the black box education, it is necessary that the problems can be solved using the knowledge gained in a given moment. We consider the tasks aimed at text ciphering using the following types of ciphers to be suitable exercises (particularly for Informatics) (Figure 3):

- **Cheaters** – the principle lies in inserting of a selected string to a chosen place in the original text. For example, each vowel will be succeeded by the consonant ‘p’ and the vowel itself, ‘i’ will be ciphered as ‘ipi’, ‘o’ as ‘opo’ etc.
- **Transposition ciphers** – the principle lies in preserving the former identity of a character, the only occurring change is the one of its position.
- **Substitution ciphers** – the principle lies in preserving of the position of a character and in the change of its identity.



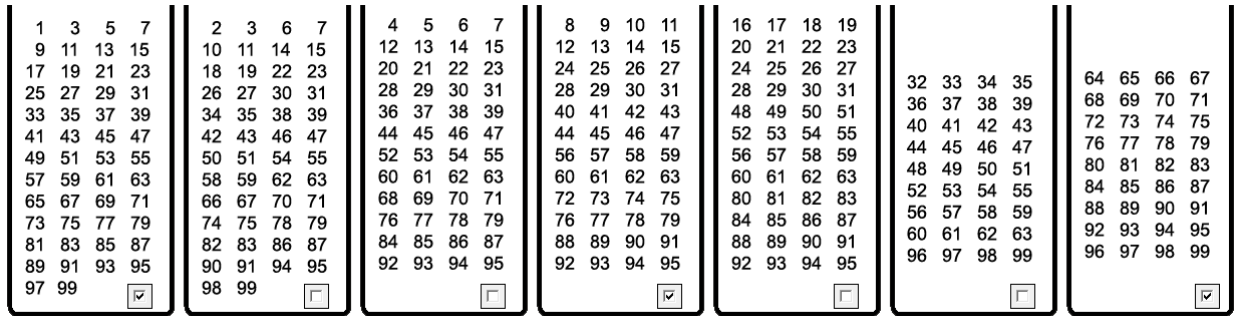
Figure 3. Ciphering algorithms – Cheater, Transposition, Substitution

#### 3.3. Positional notations

This type includes more difficult tasks; a standard example is the one of so called Magic pots. The application can be designed in several versions that differ according to the number of pots and also the number of elements in

them. The task could read: “Think of a number from interval 1 to 99. Look carefully into each of the pots bellow. There are 7 of them. Mark the pots that include your number. Note that the number can occur in several pots. When you mark the pots, press OK and I will try to guess your number. (Figure 4)”

It is obvious that there is an algorithm hiding behind the mind reading, a one that transforms the user’s input (marking of the pots) into one output number (guesses the thought number). The student will probably repeat the process several times using different numbers, trying to figure out the secret procedure. While it is obviously not about a one-element intersection of the marked sets, it is necessary to examine the attribute common for all of the elements in a set.



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Figure 4. Magic pots

At first, it is possible to think that the computer applies the operations of intersection, finding the common elements of the pots very quickly. This “magic trick” has the advantage of the option of being executed even without a computer, applying the needed (simple) operations by heart, which can be presented right away. The pots can be printed out making it possible to execute the magic trick as an informatics activity without computers (Bell et al. 2009).

An attentive student will notice, after several repetitions, that the computer guesses the thought number by adding up the first numbers of the marked pots. The student thus knows how the computer guesses the sought number. But our goal is not only for the student to find out how the computer guesses the number, but also why the computer proceeds this way (Cápay et. al., 2006). We want her/him to discover the rule, according to which the numbers are put into individual pots.

We can (but do not have to) draw the students’ attention to the relation of the problem to the numeral systems. The inclusion of the number in a particular set is determined by its binary notation! The algorithm uses the principle of conversion of the number from binary into decimal system. The sets, displayed on the screen as pots, correspond with the place values of positional numeral system. In table 1, the pots from figure 4 are numbered from 0, 1, 2, 3, 4, 5, 6. Symbol x represents 0 or 1 in the binary notation. Pot numbered X contains all integers from the interval <1,99> with the corresponding form of their binary notation. If we know on which positions are the ones in the binary notation of the number, we can definitely determine the value of the number.

pot	Numbers in binary notation	pot	Numbers in binary notation
0	xxxxxxx1	4	xx1xxxx
1	xxxxx1x	5	x1xxxxx
2	xxxx1xx	6	1xxxxxx
3	xxx1xxx		

Figure 4 shows situation in which the pots 0, 4 and 6 were marked. They show the positions of ones in the binary notation of the thought number. The binary notation of the number is 1001001. We will get the value of the thought number after conversion into decimal system:  $1 * 64 + 0 * 32 + 0 * 16 + 1 * 8 + 0 * 4 + 0 * 2 + 1 * 1 = 73$ .

### 3.4. Algebraic modifications

The algorithm works on a principle of successive instructions for the user from the black box. It begins with the instruction “think of a number...” followed by a sequence of instructions containing mathematical operations such as “add...”, “subtract...”. In the end, the application, despite not knowing the number you have thought of, “guesses” the result the user got following the instructions on mathematical operations.

- |   |  |
|---|--|
| 1. Think of a number from 1 to 10.        | 5. Subtract the original number from the result and multiply by 2. |
| 2. Add 8 to it and multiply the sum by 2. | 6. Add 9.  |
| 3. Subtract 16 and multiply by 2 again.   | 7. The result is 25.   |
| 4. Divide by 4 and add 8.                 |  |

The algorithm is designed so that the operations of addition, subtraction, multiplication and division are served to the user strategically according to a set key (formula 1). The original value will be eliminated in one of the steps, making it irrelevant to the total result of the expression. Thus, the algorithm never really counted the thought number; instead it made the user think of the number chosen by the algorithm. It would be appropriate to parameterize the tasks of this type so that the user will always get a different, random result while experimenting with the black box (formula 2).

$$\left\langle \frac{\{(a+8) * 2 - 16\} * 2}{4} + 8 - a \right\rangle * 2 + 9 = 25 \quad (1)$$

$$\frac{\{(a+X) * Y - Y * X\} * Z}{Y * Z} - a \dots \quad (2)$$

## 4. Conclusion

The contribution of the BBM lies in development of students’ curiosity, systematic approach and critical thinking while gaining new knowledge. (Guniš et al.) We teach them the basic skills of scientific approach: to analyze the current situation, lay hypotheses and consequently verify the correctness of uttered assumptions. We presume that a student preferring an active and intuitive learning style will get better results in experimenting (Felder-Silverman Index of Learning Styles) than her/his classmates. This can be grounds for another research. We mostly presented the tasks on a variety of trainings and educational workshops (Cápaj et al. 2011a, 2001b) where they provoked very intense reactions and even activated the teachers themselves. In our experience, applications functioning as the Black Boxes were proved to be the adequate “recovery” activities within longer lectures (university) as well as an example of playful learning activities. This concept can be used in teaching, or even in leisure activities, for the activation of students. The activities described in the paper can be extended on the programming lessons.

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