

DEVELOPMENT OF LOGICAL THINKING USING EXCEL

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Abstract: Nowadays full of information technology, it is important to provide valuable information in teaching or research that can adapt the content of education to the needs of a rapidly developing society. It is our targeted step towards achieving the desired adaptation of educational content to provide such suitable application materials using the Excel. The computing systems guide the development of abilities and the basic factors of students' thinking in learning mathematics. The use of these tools in solving various practical problems truly penetrates all mathematical disciplines and today we are able to solve the most diverse mathematical problems thanks to properly designed program. Nowadays, there are many modern complex environments such as Excel, whose use in selected mathematical applications we want to bring near at least briefly in our article. The Excel software provides us with various implemented functions, commands and programming language enabling implementation of various algorithms. Our work is focused on creating several tasks for the development of logical thinking. Tasks are in the form of application examples using cross-subject relationships. The assignment of tasks is for students of vocational schools of economics. The tasks use the logical function "IF" in Excel and focus on the application of knowledge from specialized subjects. To use this function, it is necessary to formulate a logical test that has a clear criterion and exhausts all cases that may occur in decision making. Using Excel also offers the opportunity to expand tasks and then experiment with tasks. The information presented in our article can be used in various mathematical disciplines to solve or automate the solution of a wide range of problems, so that the text can be used by students who are just beginning to use the Excel environment to solve and understand the principle of problems using the implemented functions such as a „IF“ condition.

Keywords: logical test in Excel; Hawk-Dove model; BlackJack; Minesweeper; Eight Queens Problem; Knight on the chessboard

1 Introduction

Recently, there has been more talk about the need to develop logical thinking. This pressure to develop logical thinking is because logical thinking does not only serve the needs of the subject being taught but is also a key factor in integrating an individual into society. Interdisciplinary relationships can be used to develop logical thinking. When applying cross-subject relationships, tasks become more demanding, but their real focus makes them more interesting for students. Also, the inclusion of cross-subject relationships forces students to reach the knowledge. When solving such tasks, it is necessary to identify and classify the problem in the first step. The subsequent solution is already specific to the task.

One of the greatest human priorities is the ability to adapt. The development of scientific and technological progress is also related to the involvement of computation technique and computers in social life. Consequently, education has been adapted to this progress by including Information and Communication Technologies (ICT) into the educational environment. In the work [1], the author points out the motivational aspects of ICT, the necessary skills for using ICT in teaching and the possibilities of searching and processing information, immediate feedback and visualization, thus offering a different perspective on the subject matter. In the paper [2], we see a focus on an ICT device, an interactive whiteboard, and find the impact of this inclusion in the classroom. The work points out the advantages of the interactive whiteboard for speeding up learning, raising students' attention or better classroom management. It points out the disadvantages of home teacher training when preparing the applications for lessons and the affordability of the interactive whiteboard. A critical view of the use of ICT in teaching can be found in the article [3], in which the author points out the benefits of ICT, which are discussed but have not been unequivocally proven. A similar critical view of ICT can be found in [4]. In this work, the author compares traditional teaching with teaching supported by ICT. It points out the disadvantages of software in classes with a large diversity of students. In this case, the teacher's preparation for the lesson is more difficult. Direct work on the relationship between ICT and teaching mathematics can be found in the publication [5]. Here, the author points out the advantages of ICT in the teaching of

mathematics, such as the possibility of visualizing the problem, facilitating computational problems and didactic games in the ICT environment. The general characteristics of ICT can be found e.g. in work [6], where the author observes the inclusion of ICT into the educational environment. It highlights the benefits of ICT, both as a tool for information retrieval and knowledge testing. Also, it points to the creation of conceptual structure using hyperlinks, where, based on the keywords in the text, we can create more complex information structures. Another publication focusing on ICT and education is [7] in which the author focuses on modernizing education and information literacy, which is gradually ranked among the necessary skills of the current era. For specific use of ICT in mathematics, book publication [8] focusing on teaching CAS-supported mathematics, i.e. computer algebra systems, is appropriate. The thesis points out the advantages of involving this software in teaching and the differences between the numerical solution and analytical solution of special examples. Some tasks act as motivational tasks for each type of software. The use of ICT in mathematics is also addressed in publication [9] which highlights the modernization of teaching through the appropriate inclusion of ICT and the possibilities of electronic textbooks, dynamic geometric software, and graphic calculators.

In addition to the general use of ICT in teaching, spreadsheets teaching is a separate category. In the article [10], we find a brief overview of the history of spreadsheets in the teaching process and the primary use of calculators in teaching databases and plotting function using LOTUS 1-2-3. Spreadsheet calculators such as SuperCalc, MultiPlan or PlanPerfect, and many others gradually replaced the emerging versions of Excel, whose predecessor was MultiPlan. Beginning versions of Excel gradually created an educational environment for the introduction to programming and the creation of various computational algorithms. Direct inclusion in the teaching of mathematics points to the possibility of using Excel for various experiments in the field of number theory, combinatorics, statistics or probability. In terms of application, Excel has come to the forefront both in commercial use and in teaching. An interesting task that requires some skills in the Excel environment but has a motivational character for students is the familiar Sudoku puzzle. See [11] for instructions on how to build a Sudoku puzzle using Excel. In addition to the instructions, there are also methodological notes for teachers. The use of Excel in teaching probability can be found e.g. in the work [12]. In this paper, the author uses Excel to simulate random phenomena such as coin-flipping or dice rolling and points out the distribution functions of random phenomena. Another application in the teaching of mathematics can be seen in the work [13]. In this work, we see the use of Excel in solving non-linear equations using two methods. The first method is graphical, in which it is possible to draw a graph that can be zoomed in at selected intervals and get a solution with any accuracy. The second way is a numerical solution, which offers us also the possibility of a specified accuracy. Among other ICT-related work in mathematics, work [14] is of interest. In this work, the author uses Excel to model various natural and physical phenomena. The work thus points to the possibility of using the Excel environment to zoom in to selected areas e.g. in biology and physics. Using numerical and graphical solutions, it also presents demanding problems, such as population growth or free fall of a body in an air resistance environment. A similar use of Excel to simulate physical phenomena can be found in [15]. The possibility of Excel to prepare future mathematics teachers can be found in publications [16]. Here, the author points to a mathematical game, which is subsequently modified for the Excel environment, and the difficulty of which can be gradually modified and changed. As we can see, the Excel environment offers a few applications and thus deserves to be included in the learning environment as a supporting ICT tool. To better apply Excel in the teaching of mathematics, it is necessary to summarize the functions of mathematics of today's teaching of mathematics.

2 Mathematics functions and problems in mathematics

The development of natural sciences and technology leads to discoveries and to the use of many different laws needed to solve difficult problems, using extensive calculations based on special mathematical methods. Mathematical concepts and theories are directly related to the material world that surrounds us. It follows that the concepts are derived from reality, although many were created by multiple abstractions. Also, the logic in mathematics is the same as in other natural sciences, even the position of logic in mathematics is much higher. Empirical conviction suffices about the truth of the phenomenon in other sciences, while in mathematics the main emphasis is on the logical structure and its consequences. An example of the geometry of the sum of the internal angles in a triangle is a good example of this difference from other sciences. From an empirical point of view, it is correct to say that the sum of the internal angles in the triangle is $\alpha + \beta + \gamma = 180^\circ$. On the other hand, by examining the sum of the internal angles of the triangle, it led to the development of geometry and the division of geometry into Euclidean geometry and non-Euclidean geometry. Both types of geometry have their representation in the real world. There is often a discovery, or generalization, in science that overtakes the scientific field for a long time, and this creates the foundations for the scientific discipline. If such discoveries do not immediately have their application in practice, we speak of pure (theoretical) mathematics. In this case, a set of new knowledge and computational techniques is created, ready for later use. Examples of this are e.g. the discovery of non-Euclidean geometry that is used in relativity theory or discoveries from abstract algebra that form the basis for modern physics.

Mathematical knowledge is developed by tasks. Tasks are defined as various exercises, examples, appropriate questions and various situations that require creative activity from the student's side. An important factor is which task we present to students and in which form we present it. The tasks have different difficulty and different cognitive functions. Tasks and their solutions are creative content of teaching mathematics at all types and levels of schools. Tasks are the bearer of knowledge, abilities, and skills, they are manifestations of methods of work in the given area of human knowledge and a means of solving practical problems. From the point of teaching objectives, mathematical tasks fulfil these functions: *educational* (aimed at forming mathematical knowledge, habits and skills at different levels of their acquisition), *upbringing* (aimed at shaping students' interest in independence, creativity and moral qualities) and *developing* (focused on acquiring effective ways of reasoning and thinking). In the theory of mathematics teaching, the basic functions of mathematical tasks are: *the local objective of teaching mathematics* (the tasks develop mathematical knowledge, assist in the acquisition of mathematical syllabus, and the local objective depends on the objectives of teaching mathematics), *the means of teaching mathematics* (the tasks are the tool by which we achieve the planned results) and *the means of teaching the methods of solving* (through solving the tasks we also teach the methods by which different tasks are solved). The first function of the tasks, i.e. the local objective, is related to the position of the objectives of teaching mathematics. The learning goal is most often taken as a result of teaching. These goals can be formulated in the tasks outlined in the standards. The other two functions as a means of teaching enable a comprehensive view of the whole content of the learning process. Teaching mathematics is mainly a cognitive process. We teach mathematics through tasks and simultaneously teach methods of solving mathematical problems.

Through the tasks we ensure the fulfilment of general learning objectives: *mathematical knowledge and art* (students should acquire basic mathematical knowledge and skills, abilities and insights into different mathematical topics and know how to use them, they should be familiar with mathematical methods and ways of thinking), *use of mathematics in off-mathematics areas* (students acquire the ability to use their mathematical knowledge and art in different areas, especially those related to their experience and knowledge, yet to have insights into the

problems of mathematical applications), *general abilities* (using mathematical tasks, we support the ability of exact work and argumentation, presentation and interpretation of the facts, and solving mathematical tasks also supports productive mental work and develops critical thinking) and *personal and social development* (we lead students to careful, focused, and planned work, investigating the situation and problems in solving tasks, solving them with rational thinking, but it is necessary to look at the boundaries of the use of such thinking).

In the teaching process, we look at tasks as two basic types: *standard* (memory-oriented and algorithmic thinking, the main goal of which is to practice procedures and methods of solution, these tasks do not represent an effort for the intellect and therefore do not act as a challenge for the student); and *non-standard* (this task type is more demanding because these tasks do not require a routine solution, they act as a challenge to the intellect and are motivational). There are two types of standard tasks: tasks requiring a well-known rule and tasks using repetitions already known [17]. We usually solve the first type of problems mechanically using a known algorithm. The student gets to the solution without difficulty and this type of tasks does not require any ingenuity. The second type of standard tasks focus on small, isolated objectives of mathematical knowledge. They fulfil a control function, they are assigned to the students to check whether they are familiar with the basic relationships, concepts, procedures, symbols, and their meaning. The solution of this type of tasks is memory oriented. Solving the standard type of tasks is essential for studying mathematics. Non-standard tasks are more interesting than many standard tasks but are usually more demanding. Non-standard tasks often have a motivational position in teaching mathematics and their solution is about discovering ingenuity, thinking and finding new ways to solve tasks. Developing students' cognitive abilities as one of the main objectives of the school is possible only through an active discovery process. In every task, we solve a problem in which something is objectively specified and something is unknown. We solve such problem in phases: *understanding of the problem* (orientation in the problem and its understanding), *strategic-operational phase* (thought-intensive and solving the mathematical task itself), *synthetic-verification phase* (verification of hypotheses and methods). These phases include interdependent processes: *analysis*, *synthesis* and *generalization and abstraction*. These processes are unconditionally related, and their use makes it possible to discover the unknown if they are subordinate to a specific goal. In school practice, it is a solution of the task or finding a valid rule to solve a problem. Intellectual abilities, i.e. intellectual operations abilities, abilities to understand the content, problem-solving abilities can be developed by solving non-standard tasks.

Tasks in terms of the structure of the cognitive process can be divided into: *Tasks to motivate students' learning activities* (which include tasks related to students' surroundings suitable for strategic motivation and students' interest, problematic tasks with mathematical content and historical tasks with mathematical content), *tasks for clarification and initial acquisition of essential properties of concepts and ways of solving tasks* (which include motivational tasks and tasks arranged with increasing degree of entropy so that the given knowledge arises as an abstraction and generalization of acquired experience in solving them); *tasks for fixing syllabus* (which include tasks of the type "by the pattern" or tasks of the type "find the error" and systematic and creativity tasks), *application tasks* (including tasks related to general professional basics, social and natural phenomena, or real-life learners' experience and knowledge; and tasks connected with the future vocation of students, which are closely linked to vocational and practical training for the profession), *tasks of a propaedeutic nature* (which include tasks for revising previously acquired knowledge and aptitude needed to acquire new syllabus, tasks to guide and facilitate students' cognitive activity of students in the following tasks within the thematic unit and tasks that fulfil a mainly developing function in the given thematic unit and are also preparatory tasks for acquiring the syllabus elements in other thematic units), *tasks for revising and systematizing the*

syllabus (that include the tasks for word characteristics of the method of solution of a class of tasks, the task for integrating the methods of solution, for comparing different methods of solution, the task of finding opportunities to use the knowledge in practice and other disciplines, and the task of creating logic schemes) [18].

Verbal tasks are a special type of task. This type of task is characterized by the fact that the dependence between given and searched data is determined verbally. Many of these tasks are practical. It is necessary to find out in the verbal tasks based on appropriate considerations what computational tasks we must perform to be able to answer all the questions asked based on the entered data. When solving verbal problems, it is necessary to clearly formulate the mathematical problem resulting from it and this process is called *mathematization*. A verbal task may contain information that is irrelevant to the solution. Formulating a mathematical task from a verbal task requires an understanding of the assignment of the word task and the subsequent separation of the essential information from the non-essential information. The solution of a verbal problem consists of three phases: *analysis of the task* (familiarization with the task, determining the question, determining the conditions, checking the knowledge of terms and relationships), *drawing up the solution plan* (illustration, determining the solution procedure) and *calculation* (execution of calculations, checking correctness of calculations and result, answer). Cognition is a complex process that is mediated in nature. When proceeding from the unknown to the knowledge, the student acquires information that has the value of new knowledge, i.e. the learning process is an active process of cognition because, from the student's side, it is subjectively new information. By serving a group of tasks that must be solved in a certain order, is determined the system of activity and the structure of the cognitive process. Acquiring knowledge means being able to use it in at least simple situations, which is reflected in skills and habits. Tasks that relate to the knowledge system form a task system. Any system of tasks related to a given topic should combine requirements based on the principles of the cognition process and the principles of the learning process with its external and internal conditions. Creating a task system requires procedures to be followed, e.g. logical and didactic analysis of the content, setting learning objectives and their concretization using representative tasks or creating a system of tasks, where tasks gradually represent specific didactic functions.

In addition to creating a system of tasks to acquire knowledge and competence, it is possible to create tasks aimed at developing higher cognitive functions to divergent thinking. When creating a system of tasks, it is advisable to have enough tasks aimed at mastering the procedure, but a large number of similar tasks may give the impression of a stereotype, leading to negative motivation. Also, there may be cases where a small change to a task may lead to a failure to resolve the task. To create a positive motivation in solving tasks, it is necessary: to teach students to logically analyse the tasks, not to seek solutions to a new task without former analysis, to examine the structural speciality of tasks, to seek solutions with general organization of work; to teach methods and schemes of activities and to teach students after finding a solution to do a reverse analysis of the solution in order to find another possible way of solution. The optimum situation is when the student accepts the task and solves it as his/her problem. Then the student ceases to solve the task under external pressure, which creates the conditions for the original solution.

3 Tasks for developing logical thinking solved in Excel

Computers and computing technique have a significant impact on all areas of life and therefore affect every individual. The use of computers in life is not only a matter of work but also a matter of leisure and learning. It is therefore appropriate if mathematics education is supported by ICT. By using ICT in the teaching of mathematics, we are freeing the tasks from routine calculations, whereupon we can emphasize other areas of teaching mathematics. Another option is to teach students to search and

process information. The ICT environment teaches students the appropriate questions and conditions they use to communicate with the computer and the ICT environment. The use of computer in teaching mathematics contributes to the fulfilment of various didactic functions: *motivational function* (computer use offers the possibility of experimentation, verification of various hypotheses, which can formulate a positive attitude to the issues), *information function* (by appropriate use of ICT it is possible to gather, store, process, present and disseminate information), *management function* (many tutorials are created interactively, i.e. the student receives immediate feedback and it is possible to manage an exchange of views between the student and the computer), *rationalization function* (by appropriate inclusion of ICT into the education process it is a possible control the teaching methods), *control function* (for the organization and management of the teaching process it is necessary to control the results achieved; ICT can effectively diagnose and evaluate results of the learning process), the *communication function* (ICT-supported teaching promotes mutual communication between students working in groups) and the *social function* (group work encourages discussions on the subject, weaker students acquire new knowledge in collaboration with their classmates; the role of the teacher in the teaching process is also changing and the teacher is no longer a central personality mediating the content, but only becomes an advisor to guide students).

Most definitions of logical thinking correspond to mathematical thinking to the extent that logical thinking is one of the basic parts of mathematical thinking. Also, in the teaching of mathematical logic, we often encounter the situation when the teacher leads students to master a certain algorithm, but this may deviate from the development of logical thinking. Therefore, the development of logical thinking involves not only deciding the veracity of statements based on propositional logic, but also the ability to create statements, sentences, and conditions. In Excel, the "IF" function is focused on creating conditions. Using it, it is possible to create decision algorithms, which supports algorithmic thinking, computational thinking, and logical thinking.

Tasks below are focused on "IF" condition. This type of tasks belongs to the teaching of Informatics and Information Technology at secondary economic schools. The aim of the courses in Informatics, Information Technology, and Applied Informatics is to teach students to work with information. Students will understand the basics of information technology and will learn to use the operating system, office software and work with common application software or specific software used in the relevant field of expertise. Our tasks are designed to motivate students and introduce them to a professional issue that they may encounter in their later studies. At the same time, our goal is for tasks to stimulate creativity and develop logical thinking by creating the conditions needed to solve tasks. Tasks were created to modify various well-known tasks in Excel.

Task 1: Hawk–dove

The hawk–dove example is one of the basic examples from the game theory describing social behaviour [19]. Since many of the implications of this model are known to the students from the technical subjects, this example is suitable for using Excel. The simple rules of this game offer the ability to create conditions using the "IF" function in Excel. The inspiration from nature was a designed model of the game, which reflects the real situation when a conflict arises. Position no. 1 "to agree and withdraw from requirements" represents the dove's strategy; position no. 2 "uncompromisingly enforcing its demands without the willingness to agree" is the hawk's strategy. If two doves meet, they can retreat from their requirements, so in principle, the game gets both players 5 points. If one player adopts the strategy of a dove and the other player adopts the strategy of a hawk, the dove shakes off and retreats to the hawk. In the game, this means that the dove receives 0 points and the hawk 10. The last option means that both players in the conflict situation take

the position of the hawk. Both hawks behave aggressively and in the simplified model we characterize the resulting state as an injury to both hawks and therefore both players get -10 points. Since it is a so-called evolutionary theory of games, it is advisable to create several rounds and finally count points. For a better understanding of the game, the students first played this game with each other, then against the computer, where they were already working on the algorithm, they implemented in Excel to calculate points.

When implemented in Excel, the table first defines student status and computer status. We take the computer as a random system, so we use a random number generator, where for the computer the numerical assignment 0 is a dove, 1 is a hawk. When counting points, numeric values are used to determine conditions, e.g. a dove-hawk meeting is understood as $0 - 1 = -1$, and if this condition is true, the dove has 0 points and hawk 1. The "IF" function can be used to create a multi-game strategy in which results can be used from the previous round. This offers the opportunity to experiment and look for a winning strategy in conflict resolution. To make it easier, it is advisable to create a flowchart to create a decision algorithm for point counting. The assignment of points must be created separately for both the student and the computer (Figure 1).

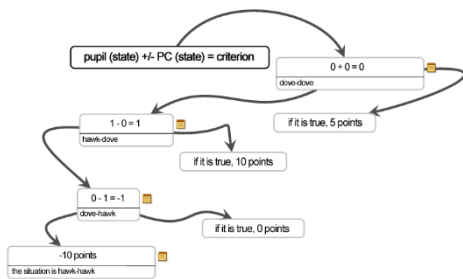


Figure 1. Flowchart for hawk-dove game solution

Then we create two tables in Excel, the first table shows the players' attitudes and the second table contains the sum of the points gained (Figure 2).

Pupil	PC	Score	Pupil	PC
0	1		0	2
0	0		1	1
0	0		1	1
0	1		0	2
1	0		2	2
1	1		-2	-2
0	0		1	1
0	0		1	1
0	0		1	1
1	0		2	2
1	1		-2	-2
		Result	5	9

Figure 2. Solving the hawk-dove task

We set the game for "PC" as random, so we used the `RANDBETWEEN (0; 1)` command to simulate it. The points for the player "Student" are determined by the command `IF (B3+C3=0;1;IF (B3+C3=2;-2;IF (B3-C3=1;2;0)))`, then we determine points for the player "PC" using the command `IF (B3+C3=0;1;IF (C3-B3;2;IF (B3+C3=2;-2;0)))`. These commands are copied in the column according to the number of rounds of the game.

In conclusion, we can say that the pupils played this game in pairs as first, so they better understood the principle of the game and started to think about winning strategies for a multi-round game. The "IF" function was used in the point counting, but the formulation of the conditions was not so clear for the students. After completing the implementation of the point counting

algorithm, students continued to experiment with finding a strategy. Preferred strategies were using the previous round, referring to real-life decision-making, considering previous experience. They used the formulation of the decision algorithm again to create a strategy referring to the previous round.

Task 2: BlackJack

The BlackJack card game is one of the most popular and, in principle, the simplest casino games. The advantage of this game is that it is not based purely on chance but offers strategy options. The predecessor of BlackJack is the French game *Vingt-Et-Un*, i.e. "21" (21 wins). As with 21 wins, BlackJack's principle is to approach 21 in the total of cards [20]. Cards numbered 2-7 have the real value of their number. Cards marked J, Q, K have a value of 10. The A-marked card has a discretionary value of 1 or 11. If we assign the value of 11, we are speaking of soft sum, otherwise, the sum is so-called hard. Depending on the cards, the player has the option of splitting the cards, which divides the game and starts a new game automatically with each card. This is also associated with doubling the stake.

To solve the implementation of this game in Excel, we need to realize that in BlackJack we use random card pulling, which we can ensure by generating random numbers. By linking random numbers to cards, cards marked with a number will retain their number, and cards with a letter will be determined using the "IF" condition. Also, when uncovering the cells that represent the drawn cards, the automatic recalculation option in cells [21] should be turned off. This will ensure that the cards are not changed during the game. Shuffle cards before a new game by pressing F9 to calculate the hand. We divide the cards in such a way that the card we want to separate (the division is according to the rules of 2 cards) is covered, i.e. the cell is coloured black. And we create a new column whose first cell has the same value as the cell that symbolizes the card. Other cells are refilled using random numbers. Unless you plan to split the cards, this column is covered, i.e. the cells are coloured black (Figure 3). To randomly shuffle cards, we use the following command: `RANDBETWEEN (2;14)`. To determine the card, use the command:

```
IF (A2<11;A2;IF (A2=11;J;IF (A2=12;Q;IF (A2=13;K;A))
```

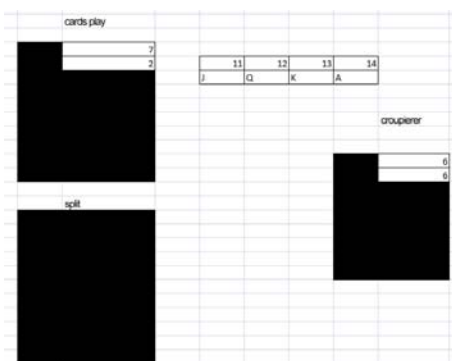


Figure 3. BlackJack game solution, swiping the card means uncolouring the black cell

Task 3: Mines

Mines play [22] belongs to computer logic games. The basis of this game is to gradually reveal the field, determining where we suppose a mine and where not. When a cell is successfully detected, we know how many mines are in its immediate vicinity. The difficulty of the game depends on the size of the field (we will create a 6 x 5 field in the task) and the probability of mines.

When solving a task in Excel it is necessary to define the basic characteristics of the task. This includes determining the size of the playing field and creating a system to determine the

difficulty. It is common to determine the difficulty in such a way that the number 1 is the lightest level and the increasing number indicates the increase in difficulty. Mines play is characterized by the fact that the mines are randomly distributed, and this leads us to use random numbers like BlackJack. Even when selecting random numbers, it is necessary to know how the difficulty will be determined. The difficulty depends on the size of the field, so we have an array with dimensions $A \times B$, where the number of cells is $n = A \cdot B$. We determine the difficulty of $d < n$, $n \in \mathbb{N}$ so that using random numbers, the probability of mine in cell $p = \frac{1}{n+1-d}$. Thus, the number of mines in the playing field will also be random. In the next step, we define the *auxiliary field 1* (Figure 4), which is hidden during the game and is used only for auxiliary calculations. We define each cell in this field as a random integer between 0 and $n - d$ using the command `RANDBETWEEN(0; C3-C2)`, with a value of 0 to determine where the mine is located. In the next step, we create an *auxiliary field 2* (Figure 5) in which we define which cell is a mine and which is not. The mine has a value of 1, the empty cell has a value of 0. For this classification, we create a condition `IF(R2=0;1;0)`, which selects the respective cell from the auxiliary field 1. If the cell in the auxiliary field 1 is 0, the value of the auxiliary field 2 is 1. Otherwise, it is 0. Thus, we will be able to calculate the number of mines touching the exposed cell later. Finally, we define the *playing field* (Figure 6). We create a condition in the playing field, if the cell in auxiliary field 2 has a value of 1, the cell writes "mine", otherwise it adds the values of cells around the cell in auxiliary field 2. By adding cell values, we get information about how many cells in proximity contain a mine. In the penultimate step, we determine the sum of the cells in auxiliary field 2 to obtain the number of mines in the playing field. In the end, we turn the tables black to start the game. In this game, you must also turn off automatic conversions as in BlackJack.

	B	C	D	E	F	G	H
difficulty			20				
field			30				
5x6				auxiliary field			1
number of mines			<code>RANDBETWEEN(0;\$C\$2-\$C\$1)</code>				
		2	5	4	8	5	4
			10	4	4	10	8
			5	9	3	3	0
			9	7	1	7	7
			6	1	2	0	8
			9	7	1	6	4

Figure 4. Auxiliary field 1 used to build the Mines game

	auxiliary field			2
	0	0	0	0
	0	0	0	0
	0	0	0	1
	0	0	0	0
	0	0	0	1
	0	0	0	0

Figure 5. Auxiliary field 2 used to build the Mines game

	playing field				
	0	0	0	0	0
	0	0	0	1	1
	0	0	0	1	mine
	0	0	1	2	2
	0	0	1	mine	1
	0	0	1	1	1

Figure 6. Playing field for the Mines game

Next, reveal the number of mines next to the exposed cell, if it is empty or contains a mine, using the command (Figure 7):

```
IF(R11=1; "mine"; Q10+R10+S10+S11+S12+R12+Q12+Q11)
```

difficulty	20				
field	30				
5x6					
number of mines	4				
	0	0			
	2				
		mine			

Figure 7. Mines game built in Excel

Creating this game in the first step required deeper analysis because of the need to create auxiliary fields. Also, when creating the level settings, it was determined how the next procedure would evolve. This included defining the conditions under which a cell contains a mine and when the cell is empty. Finally, it was necessary to determine a condition that tells us whether we hit a mine or how many mines are nearby. The game itself is focused on developing logical thinking and finding a suitable strategy.

Task 4: Eight queens on a chessboard

The problem of placing eight queens on a chessboard [23] is an old problem in the field of combinatorics. It first appeared in the Berlin magazine *Schachzeitung* in 1848, where the article's author was Max Friedrich Wilhelm Bezzel. The task speaks of arranging eight queens on the chessboard so that they do not threaten each other. This task belongs to the so-called exoproblems of the compositional chess. Exoproblems - Exoproblems are chess tasks that do not arise in a chess game. Classic exoproblems include self-mates (it is very unlikely that someone in a chess game would want to force an opponent to give him a checkmate, for this reason, this type of chess game ranks among exoproblems) and auxiliary mates (unlike the self-mates, it is not necessary to force the opponent to give us a check, but we assume rational moves from the opponent to the checkmate in this type of task). Also, it is possible to create tasks with modified rules to exoproblems. By modifying the rules, we understand the involvement of new pieces but also changes in the playing field, e.g. that the chessboard may be cylindrical or circular. In addition to the exoproblems, there are also puzzles with the so-called checkmate in two, three and four moves, etc. This includes tasks that are from a certain situation where we must complete a task within a given number of moves. The most common problems are focused on checkmate situations, or achieving a certain number of moves, e.g. capture the queen.

Compositional Chess [24] is a chess discipline aimed at solving and devising chess problems. The tasks of compositional chess must meet the basic conditions: *Originality, Legality of problems* (this condition may not be met by exoproblems), *Correctness of solution, Economy* and *Aesthetics*. Under the term legality, we consider that the situation could occur in a hypothetical game. The economy is the condition that each piece has its role in the situation.

With the Problem of the eight queens, the queen moves on the chessboard in such a way that it goes directly in the column (up-down direction), in the row (right-left direction), and along the diagonal (oblique direction), preserving the colour on which it currently stands). For endangered pieces by a queen, it means that it blocks the queen's movement. To solve the task in Excel in the first step, create a chessboard field, that is, set the cell dimensions in the selected area with dimensions $(A - H) \times (1 - 8)$ to form a square grid. Furthermore, the task follows the game of mines in thought, which is focused on orientation in the cell field. As in mines, it is advisable to use an auxiliary cell field. The chessboard consists of a square box with dimensions of 8×8 . To avoid looping of the command, we use one auxiliary

field and one output field. This way, the task will be divided into three blocks. The first block is the input field where we insert the queen as number 1. With this numerical input, we can then use the basic operations (+, -, >, <, =) to determine the condition by which the output field determines which fields (cells) are suitable for laying the queen, which fields are occupied, and which fields are endangered by queens already saved. The input field shown in Figure 8 represents the chessboard where we put the queen as number 1. The rows and columns are standard according to the chessboard, with the white box below. Marking rows and columns makes it easier for us to navigate between the input field and the output field, where we can see free positions.

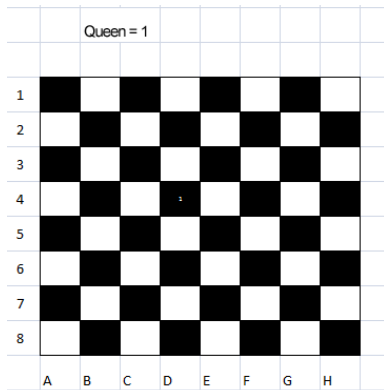


Figure 8. The chessboard on which we put the queen marked as number 1

The auxiliary field will be a chessboard with the same dimensions, but unmarked, and will be surrounded by 0 and connect it to the chessboard on which the pieces will be placed. This makes it easier for us to expand the field by zero positions (Figure 9). This means that we consider the queen's surroundings in a row, column, and diagonals up to 7 spaces.

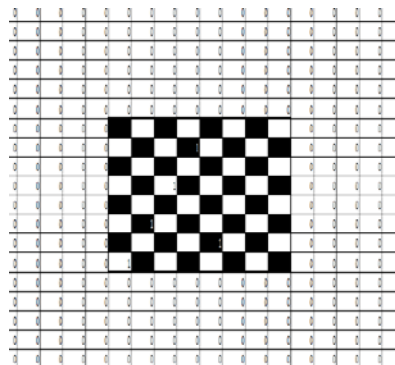


Figure 9. An auxiliary field that we use to identify fields that are endangered by a queen

Any field that threatens a queen from a certain position is a field where a laid queen would threaten another laid queen. In the output field, we insert a condition in the form: if the cell in the input field contains 1, then write "Queen", otherwise in the auxiliary block if the sum in the line minus the value of the cell is less than 0, write "endangered" if this is not true, in the auxiliary block, if the sum in the column minus the value of the respective cell is less than 0, write "endangered", if this is not true, in the auxiliary block if the sum in the diagonals minus the value of the respective cell is less than 0, if this is not the case, leave an empty cell (Figure 10). Thus, this Excel command will be:

=IF (B5=1; "Queen"; IF (T1+T2+T3+T4+T5+T6+T7+T8+T10+T11+T13+T12+T14+T15+T16>0; "endangered"; IF (L9+M9+N9+O9+P9+Q9+R9+S9+U9+V9+W9+X9+Y9+Z9+AA9>0; "endangered"; IF (L1+M2+N3+O4+P5+Q6+R7+S8+T9+U10+V11+W12+X13+Y14+Z15+AA16+AB1+A2+Z3+Y4+X5+W6+V7+U8+S10+R11+Q12+P13+O14+N1

5+M16+L17>0; "endangered"; " ")). This command is then copied over the entire chessboard, which is the output field.

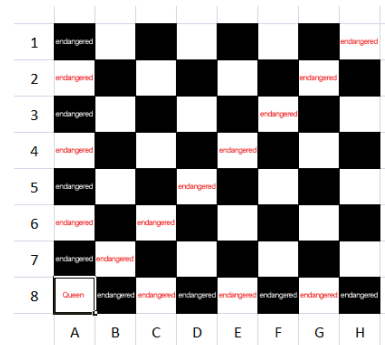


Figure 10. A working chessboard on which we have ticked boxes occupied or threatened by a laid queen

In conclusion, the Problem of the eight queens required, in the first step, an understanding of the principle of the queen's movement on the chessboard. Also, it was necessary to develop the principle of mapping the game field. When mapping the game field, we think similarly to the mines game, where we considered the cell surroundings except the cell itself. In the game of mines, all neighbouring cells formed the surrounding area, while in the problem of eight queens we consider the cells related to the movement of the queen.

Task 5: Movement of the knight on the chessboard

Chess directly affects the development of logical thinking. When playing this game, it is necessary to remember the rules and think strategically about the development of the game. When defining a game strategy, it is necessary to have, in addition to the rules knowledge, a spatial imagination of the possible distribution of pieces on the board. Also, strategy development encourages synthetic and analytical thinking, encourages creativity and patience. Another chess task we have implemented in the Excel environment is the Movement of the Knight on the Chessboard. The knight jumps in "L" shape in all possible directions from the current location so that one endpoint of the letter "L" is the current position and the other endpoint is the possible placement. If a piece is between the current position and the end position, it is skipped.

The task is directly linked to the problem of eight queens on the board. Also, in this task, it is necessary to realize first which places the knight can get from the current position (we understand these places as threatening places). As in the previous tasks, we will also use the auxiliary field to avoid cycling, as well as to avoid having to decide whether the knight is in the centre of the chessboard or on its edge. In the first step, we create a playing field (Figure 11) where we place the knight as number 1.

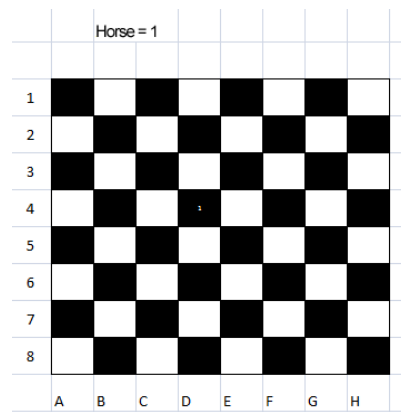


Figure 11. Input field where we insert the knight to the position as number 1

The movement of the knight is further determined by a simple condition. For the universality of the condition, create an auxiliary field (Figure 12). This auxiliary field is linked to the input field via links to get current position information in the auxiliary field. The auxiliary field is surrounded by a zero-field so that we are not limited by the edge of the chessboard.

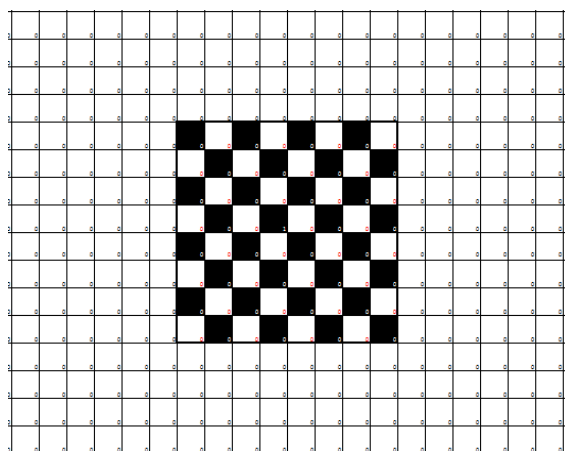


Figure 12. An auxiliary field consists of a chessboard surrounded by a zero field

The output field is linked to the helping field by a condition. If the corresponding cell has a value of 1 in the input field, an indication that it contains a knight. If it does not have a numerical value, then we create a condition aimed at checking the surrounding cell of the corresponding cell in the auxiliary field according to the movement of the knight. In the output field (Figure 13) you can see the free positions, the positions where the knight is located and the positions that the knight endangers. The process of compiling a queen's movement differs only in the last step, and our condition will have the form:

=IF(B12=1;"Horse";IF(U14+V15+S14+R15+V17+U18+S18+R17>0;"endangered";" ")). This command is then copied over the entire output field.

1	■	■	■	■	■	■	■	
2	■	■	■	■	■	■	■	
3	■	■	■	■	■	■	■	
4	■	■	■	■	■	■	■	
5	■	■	■	■	■	■	■	
6	■	■	■	■	■	■	■	
7	■	■	■	■	■	■	■	
8	■	■	■	■	■	■	■	
	A	B	C	D	E	F	G	H

Figure 13. Output field for the knight's movement, we see where the knight is located, and which fields endanger his movement

Using this task, we were able to bring the knight on the chessboard closer to the students and thus increase their orientation on the chessboard. The solution of the task itself is in the formulation of a simple condition through which we can map a chessboard field. The task does not have to be completed by making an output field, but students can then experiment with the layout of the knights on the chessboard.

4 The survey and results

Tasks were included in the teaching at the economics-type secondary vocational school in the 3rd and 4th years at the Applied Informatics classes, in the order given in this paper. The

tasks created should serve to test the ability to use the "IF" function. After solving the tasks, the students were to evaluate the tasks based on the questions asked:

1. Did you like the tasks we assigned to you?
2. Do you feel that these tasks will help you work in Excel?
3. Do you consider teaching in Excel to be beneficial?

Student assignments rated 1-5, with 1 being the best and 5 the worst (Figure 14).

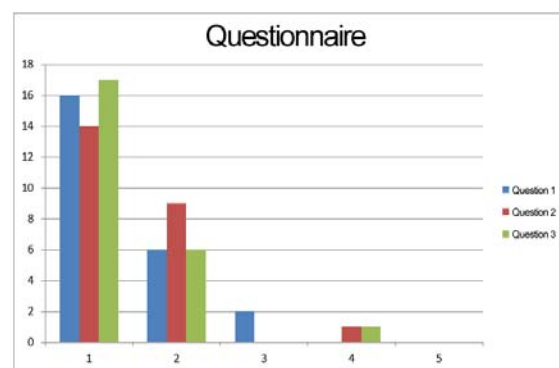


Figure 14. Student's assessment of tasks

In addition to grading, some students also gave a verbal assessment. For example:

Student 1:

1. I really enjoyed the tasks even though I didn't finish some. Evaluation 2.
2. Tasks can help me work better in Excel. Evaluation 1.
3. I find teaching Excel very beneficial. Evaluation 1.

Student 2:

1. It was nice because we had it linked to the information usable in practice and it wasn't somewhat general. Evaluation 1.
2. Tasks helped me get to know Excel better, at least taught us how to use Excel functions that I haven't even known before, and I haven't really known that Excel can do that. Evaluation 1.
3. I find Excel to be beneficial depending on the sector I will work in. Today, in almost every job, employers require employees to have at least a basic knowledge of MS Office programs, and charts that Excel can create can be used in other studies or at work. Evaluation 1.

We can conclude from our research that almost all students managed tasks 1 and 2 without major problems and the remaining tasks on average 19 out of 23 students. It can be assumed that the solution of tasks was important for the development of logical thinking at the level of creating logical conditions, i.e. the ability to create a logical condition within the solution of the task. On the other hand, the tasks also had their motivational level, which visibly influenced students. To assess the motivation level, we used a questionnaire method to find that the tasks were interesting for students. From the results, we can consider it appropriate to include the created tasks into the teaching process, as their solution makes it easier for students to learn to create logical conditions.

5 Conclusion

Logical thinking is an important form of thinking that is needed in the school environment, but it is also necessary to develop logical thinking for the needs of life. Logical thinking is aimed at creating a progressive sequence of thought operations for information processing. This principle of logical thinking is the basis for solving our created tasks. Solving tasks directly

depends on the first step in identifying and classifying the problem. Subsequently, a logical test is created, which depends on the given task. The logical test must meet the clarity of the decision criterion and, at the same time, it must cover all possible cases that may arise in the solution. The difficulty of the tasks gradually increased, but it was possible to use the analogy with the previous task. The "Minesweeper" game was known to students from everyday life, which made it easier to identify the problem in the task and to establish a logical test to create a decision condition. The role of "Hawk-dove" is known from the theory of games and it is important to include it in understanding social and economic systems. To understand its principle, but also for better motivation for this game, students have included it among themselves. After verifying the functionality of the Excel application created, students also can create strategies for multi-round games. Created BlackJack games or chessboard games develop logical thinking, even when creating applications, we could see how students changed their view of these games and strategies when playing these games. All the tasks mentioned and included in the teaching and testing were focused on the logical function "IF", which emphasizes thinking under conditions. This style of thinking under conditions then continues to create a logical test that is characteristic of each task and requires an understanding of the principle of the task. Based on the verification of tasks in the lesson, we may find it appropriate to include these tasks in the teaching process and thus help to develop logical thinking at the secondary school level.

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Primary Paper Section: B

Secondary Paper Section: BA, IN