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Preparation and Application of Mind Maps in Mathematics Teaching and Analysis of their Advantages in Relation to Classical Teaching Methods

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Abstract

In this article, we are dealing with mind maps and describing the experiment with the application of mind maps in teaching mathematics at secondary schools. The experiment is aiming at comparing classical teaching and learning with mind maps. In the past, we created two groups of students (25 students per group), an experimental and a control group. We have set up a pre-test consisting of tasks not related to the subject that will be taken through mind maps. By the end of the experiment, we apply a post-test with tasks directly focused on the subject that we will teach through mind maps. We will then evaluate the individual tests and then we will evaluate the effectiveness of the mind maps in the teaching process compared to the traditional methods.
Keywords: mind maps, experiment, mathematics, application, pre-test, post-test, comparing

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1. Mind Maps

Mind maps are diagrams that express essential relationships between terms in the form of claims. The statements are represented by briefly characterized combinations of terms that describe relationship information and describe the interrelation of concepts. The mind map illustrates the structure, hierarchy, and the relationship between the terms. It enhances the learning process efficiency and promotes creativity. They are very economical in expressing a very complex content, helpful to memorize, allowing a view of the same thing from multiple angles, allowing see the relationships between ideas in a complex way [8]. They also help to see paradoxes and opposites, which motivates students to ask new questions. It is very important to determine the central idea, from which lead the main and the secondary branches, which gradually form certain relations. We use different colors, shortcuts, diagrams, symbols, equations, and images in the map.

Mind maps as a schematic expression of thoughts, ideas or notes are not inventions of the 21st century. In addition, the use of learning methods built on the creation and presentation, which are logically arranged and the links of the conjugated terms are not the discovery of current educational trends. In the past, teachers structured the learned curriculum by using key concepts placed on a magnetic board, notice board, or complemented the prepared schemes with cutout images and characters. Many important artists and geniuses, such as Leonardo da Vinci, Michelangelo, Isaac Newton, Pablo Picasso, Thomas Edison, Galileo, Marie Curie and others, brought certain schemes into their own ideas in the past. They tried to highlight their ideas, not just linear, using lines and words, but also with a strong language of images, drawings, schemes, codes, symbols, and graphs [1].
In current professional, as well as popular-learning literature, we can encounter several names of the linear and nonlinear layout of concepts, data and main themes in graphically integrated structures. The authors present conceptual maps, mental maps, thought maps, cognitive maps, semantic maps, knowledge maps, webs, mind maps, and so on. Some of these terms do not distinguish individually and call their collectively mental maps or cognitive schemes [2].

J. D. Novak [3] considered as a founder of conceptual map theories and their construction speaks of mind maps as a hierarchically arranged, graphical representation of relations between selected concepts. There are general terms at the top of the map that are associated with terms that are more specific in the lower tree level. From the central concept, the "branches" are connecting with the concept in the lower parts of the map, from which the "branches" are connecting again with the concept at the lower levels of the map.

Psychologists Veselský [4] and Stewart [5] talk about conceptual maps as graphical imaging systems, whose basic building unit are concepts. They are represented by frames with inscribed notional names and the relationships are expressed by marked orientated lines linking the respective conceptual expressions. Focus on the non-linear abstract representation of the structure of the subject and notes an opposite to the written, printed, projected, or otherwise presented text followed by the sentences one after the other [6], stresses Mareš. According to him, it is based on the idea of organizing the best and the most transparent key concepts and relationships by "visualizing" them and creating a sketch, a schematic of an easily accessible abstract "outer" memory. Although a learner learns to organize the key elements of the curriculum on paper first. He has to begin with organizing them in the head. Thus, he is forced to consciously construct and reconstruct a network of concepts and relationships in his "mental space" [7].

It follows from the above that there is no terminological unity and consensus among the experts in understanding the different concepts of capturing concept ideas in the graphical structure of related concepts with the designation of relationships and links between them. The Fisher’s definition of mind maps is probably the most precise according to them. A conceptual, thought-based, or otherwise called mental map is a diagram that illustrates the context and relationship between knowledge, serves to organize them. We understand the conceptual, mental or idea map as synonyms. We do this in particular because some of the used conceptual maps do not have a typical structure of mental maps, they consist of several levels, and there are significant links − relationships between some terms [2].

2. Preparation, Application and Evaluation of the Pre-Test

If we wanted to compare the two different teaching methods, we needed to have the experimental and control groups at the same level of knowledge before the comparisons began. To test knowledge of these groups, we created a pre-test that tested both groups before applying the mind maps. Students in both groups wrote this pre-test on the same day. The pre-test included three tasks from the previous non-geometry related lesson. Tasks aimed at adjusting the fractions, creating, and solving the equation. In each assignment, we identified several characters, which we took into consideration during the evaluation and allowed us to compare the two groups of students more objectively.

Pre-test, Task 1: Determine when the expression is meaningful and adjust it to the simplest form.	
$\dfrac{\dfrac{a+b}{a-b}-\dfrac{a-b}{a+b}}{1-\dfrac{a^2+b^2}{a^2-b^2}}:\dfrac{\dfrac{1}{b^2}-\dfrac{2}{b}+1}{2-\dfrac{1+b^2}{b}}$	Rated characters in task # 1: • $a \neq b$ • $b \neq 0{,}1$ • transcription for multiplication • common denominator • modifying a fraction • cutting fractions • excluding -1 from the second fraction • result
Pre-test, Task 2: If we enlarge one side of the square by 4 units and at the same time reduce the other side by 2 units; we create a rectangle whose content is 12% larger than the square. Specify the square size of the square.	
	Rated characters in task # 2: • picture • content of a square • rectangle content • increase content by 12% • equality of contents • edit quadratic equation • result
Pre-test, Task 3: If we increase the unknown number by 7 and if we create the square root of this enlarged number, we get a number that is by 5 smaller than the original number. Specify an unknown number.	
	Rated characters in task # 3: • enlarged number • root • reduced number • equality • squaring • writing of quadratic equation • modification of quadratic equation • writing results

The selected characters represented the various conditions within the given task, important for its solvability, mathematical operations, mathematical entries, various comparisons, adjustments of equations, fractions and results of individual tasks. The choice of characters within the assignments helped us evaluate the solution of these tasks objectively without any external influence.

Picture 1: Selected sample of students in pre-test, experimental group, Task 1

a ≠ b	b ≠ 0,1	transcription for multiplication	common denominator	modifying a fraction	cutting fractions	excluding -1 from the second fraction	result
N	N	N	N	N	N	N	N
N	N	N	N	N	N	N	N
N	N	Y	Y	N	N	N	N
N	N	Y	Y	N	N	N	N

Picture 2: Selected sample of students in pre-test, experimental group, Task 2

picture	content of a square	rectangle content	increase content by 12%	equality of contents	edit quadratic equation	result
Y	N	Y	N	N	N	N
N	N	N	N	N	N	N
Y	Y	Y	N	N	N	N
Y	Y	Y	N	N	N	N

Picture 3: Selected sample of students in pre-test, experimental group, Task 3

enlarged number	root	reuced number	equality	squaring	writting of quadratic equation	modification of quadratic equation	writting results
Y	Y	Y	Y	N	N	N	N
Y	Y	Y	Y	N	N	N	N
Y	Y	Y	Y	N	N	N	N
Y	Y	N	Y	N	N	N	N

Picture 4: Selected sample of students in pre-test, control group, Task 1

a ≠ b	b ≠ 0,1	transcription for multiplication	common denominator	modifying a fraction	cutting fractions	excluding -1 from the second fraction	result
N	Y	N	N	N	N	N	N
N	N	Y	Y	N	N	N	N
N	N	Y	Y	N	N	N	N
N	N	N	N	N	N	N	N

Picture 5: Selected sample of students in pre-test, control group, Task 2

picture	content of a square	rectangle content	increase content by 12%	equality of contents	edit quadratic equation	result
N	Y	Y	N	N	Y	N
Y	N	N	N	N	N	N
N	N	N	N	N	N	N
N	N	N	N	N	N	N

Picture 6: Selected sample of students in pre-test, control group, Task 3

enlarged number	root	reuced number	equality	squaring	writting of quadratic equation	modification of quadratic equation	writting results
Y	Y	Y	Y	N	N	N	N
Y	Y	Y	Y	N	N	N	N
Y	Y	Y	Y	N	N	N	N
N	N	N	N	N	N	N	N

We evaluated the pre-test as the ratio of the characters in the resolution (Y means, that character was in resolution, N means, that character was missing in solution) from all students within the given task to the total number of characters within the given task. In Table 1 there is shown percentage of students' success rate in each group in a particular task.

Table 1: Comparison of pre-test results in experimental and control groups (%)

Task / Group	Experimental	Control
Task 1	10.2	5.7
Task 2	14.3	15.6
Task 3	33	34

Even though the students did not properly calculate the tasks, it was clear from the pre-test that both groups of students were about the same level of knowledge, what was essential for our experiment and we could move to the next stage, the application of mind maps in the teaching process.

3. Application of Conceptual Maps in the Teaching Process in the Subject of Mathematics

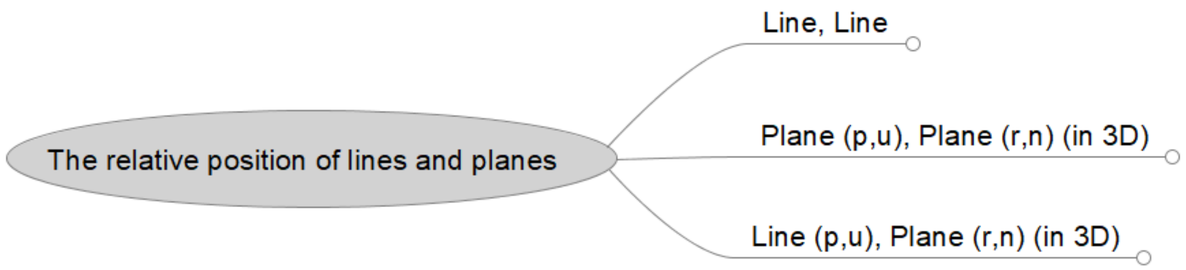
After agreement with the mathematics teacher in the experimental group, we had three lessons available, during which we presented the curriculum of geometry dealing with the mutual positions of lines and planes.

We used a computer and a projector for this activity. The curriculum was processed using conceptual maps and inserted into the presentation.

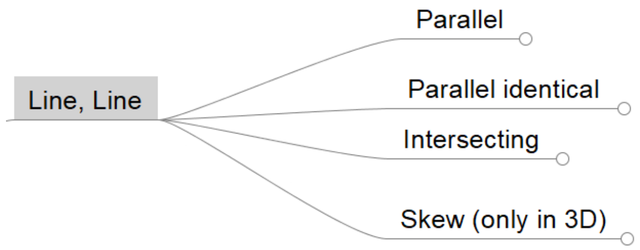
We divided the curriculum for lessons into individual groups as follows:
1st lesson: Mutual position of lines (parallel, parallel identical, concurrent),
2nd lesson: Mutual position of lines (skew), mutual position of lines and planes (parallel, parallel identical),
3rd lesson: Mutual position of lines and planes (concurrent), mutual position of planes (parallel, parallel identical, concurrent).

We informed students about the content for next three lessons.

Picture 7: Introductory division of the curriculum

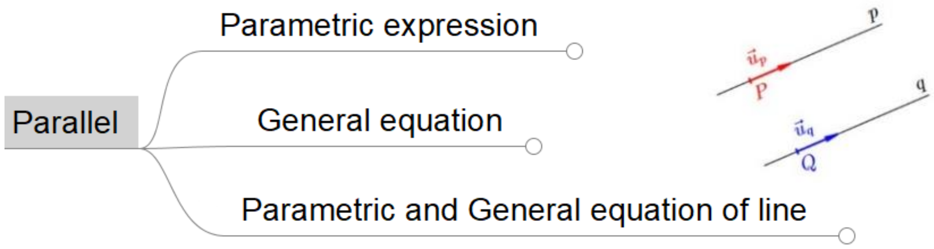


Picture 8: Detailed division of the mutual positions of the two lines



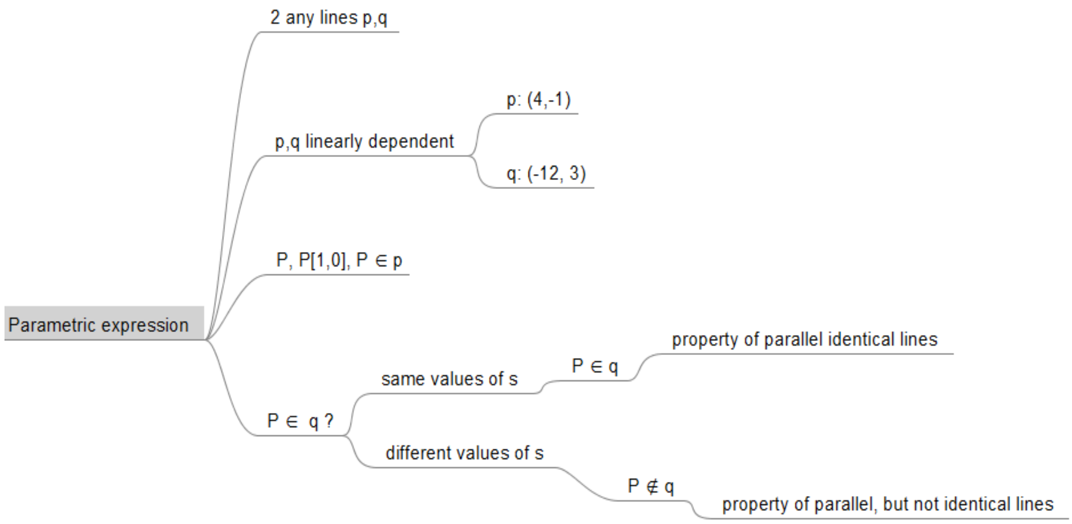
In Picture 8, we have explored in more detail the possible mutual positions of the two lines.

Picture 9: Detailed division of the parallel positions of the two lines



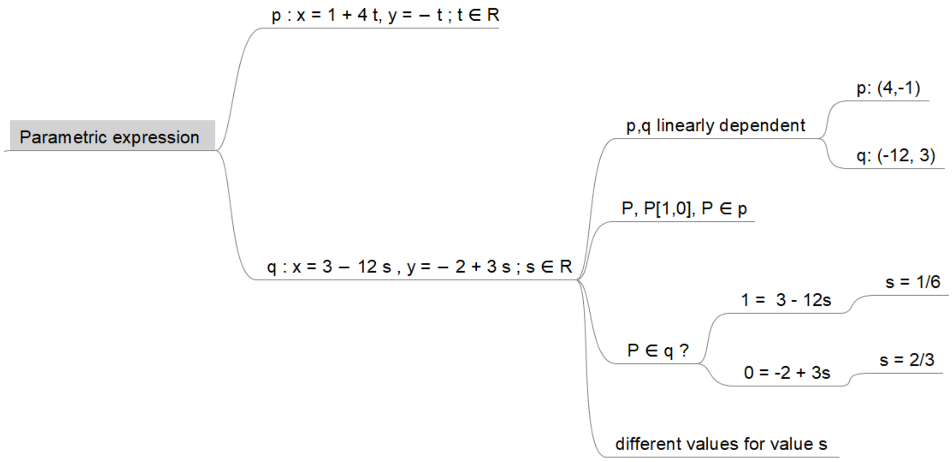
Picture 9 focused on the case of two parallel lines and the possible representation of these lines.

Picture 10: Detailed parametric representation of mutual parallel positions of two lines



In Picture 10 there is an illustrative and detailed description of a branch of parametric representation.

Picture 11: An example of the mutual position of two parallel lines in parametric representation



In Picture 11 there is task, which the students were trying to solve after the theoretical part was completed. On the map there were marked intermediate results that served to students for check.

As can be seen in Picture 7 – 11, the principles of the mind map were retained. The deeper we got into the mind map, the more specific terms were in that part. Our task was to explain these concepts to the students so they can join these concepts together alone and can apply them in solving different problems. After these three lessons, during which we were teaching using mind maps, we moved into the final phase of our experiment.
This part consisted of the post-test we gave to the students. The post-test consisted of tasks that focused directly on the subject discussed at our three lessons.

4. Preparation, Application and Evaluation of the Post-Test

After completing the pre-test, which showed us that the students are about the same level of knowledge, following the use of mind maps in three teaching lessons, we have reached the final stage of our experiment. This final phase consisted of two phases: application of post-test and evaluation of results from post-test. The tasks in the post-test were, this time, directly focused on the mutual positions of planes and lines, in order to compare the effectiveness of this method in the experimental group against the classical way of teaching in the control group. In the given tasks, we have re-selected the characters that represented the key elements in the solving of the task.

Post-test, Task 1: Show that the planes α and β are concurrent and write the parametric representation of the intersection of these planes.	
α: $5x – 3y + 2z – 5 = 0$ β: $2x – y – z – 1 = 0$	Rated characters in task # 1: • normal vector p • normal vector q • vector products • parameter at point P • parametric representation of intersection

<table>
<tr><td colspan="2">Post-test, Task 2: Determine the mutual position of plane β and line p.</td></tr>
<tr><td>$\beta: x - 5y + 4z - 6 = 0$

$p: x = 2 - t, y = 3t, z = 3 + 4t, t \in R$</td><td>Rated characters in task # 2:
• placing p to β, scalar product
• place P into equation β
• adjusting equation after placing P into β
• determine final position</td></tr>
<tr><td colspan="2">Post-test, Task 3: Determine the mutual positions of p, q. If p = $\overleftrightarrow{(AB)}$, q = $\overleftrightarrow{(CD)}$</td></tr>
<tr><td>A = [7, 6]
B = [6, 8]

C = [6, -5]
D = [4, -1]</td><td>Rated characters in task # 3:
• line p
• line q
• expression of p
• expression of q
• vector comparison
• computation and comparison of parameters
• result</td></tr>
</table>

Picture 12: Selected sample of students in post-test, experimental group, Task 1

normal vector p	normal vector q	vector products	parameter at point P	parametric expression of intersection
Y	Y	Y	Y	Y
Y	Y	Y	Y	Y
Y	Y	Y	Y	Y
Y	Y	Y	Y	N

Picture 13: Selected sample of students in post-test, experimental group, Task 2

placing p to β, scalar product	placing p to β, scalar product	adjusting equation after placing P into β	determine final position
Y	Y	Y	Y
Y	Y	Y	Y
Y	Y	Y	Y
Y	Y	Y	Y

Picture 14: Selected sample of students in post-test, experimental group, Task 3

line p	line q	expression of p	expression of q	vector comparison	computation and comparison of parameters	result
Y	Y	N	N	Y	N	N
Y	Y	Y	Y	Y	Y	Y
Y	Y	Y	Y	Y	Y	Y
Y	Y	Y	Y	Y	Y	Y

Picture 15: Selected sample of students in post-test, control group, Task 1

normal vector p	normal vector q	vector products	parameter at point P	parametric expression of intersection
Y	Y	N	N	N
Y	Y	Y	Y	N
Y	Y	Y	Y	N
Y	Y	Y	Y	Y

Picture 16: Selected sample of students in post-test, control group, Task 2

placing p to β, scalar product	placing p to β, scalar product	adjusting equation after placing P into β	determine final position
Y	N	N	N
N	N	N	N
Y	Y	Y	Y
Y	Y	Y	Y

Picture 17: Selected sample of students in post-test, control group, Task 3

line p	line q	expression of p	expression of q	vector comparison	computation and comparison of parameters	result
Y	Y	N	N	Y	N	N
Y	N	N	N	N	N	N
Y	Y	N	N	Y	N	N
Y	N	N	N	Y	N	N

The post-test was evaluated in the same way as the pre-test and the results from both tests were subsequently recorded in Table 2

Table 2: Comparison of the results of the post-test in the experimental and control group (%)

Task / Group	Experimental	Control
Task 1	88.3	78.3
Task 2	91.7	68.8
Task 3	82.1	53.6

As we can see from Table 2, the results compared to the pre-test are much better. The students were able to apply the acquired knowledge in solving of the given tasks. For our experiment is much more important that the results achieved in the experimental group, in the group where we were teaching with the help of mind maps, are obviously better than in the control group where the classic teaching methods were used.

5. Conclusion

This article was focused on the application of mind maps in the teaching process and the comparison of the mind map's effectiveness with the classical way of teaching. This comparison consisted of three important steps:

1st Pre-test and evaluation
2nd Application of conceptual maps in the teaching process
3rd Post-test and evaluation

In both tests, pre-test and post-test, we chose the rated characters which we were looking for during the correction of students' tests. We subsequently evaluated and compared these rated characters. The students wrote the tests on the same day to prevent the possible influence and improvement of the results in one or the other group.

In the first step, we gave the students a pre-test, in which the balance or imbalance of students' knowledge in the experimental and control group should be demonstrated. The results of the pre-test showed that the students were about the same level of knowledge.
In the next step, we had three lessons from the geometry. Subject of these lessons was the mutual positioning of the lines and the planes. During these lessons we were using mind maps.
In the last step, the students wrote a post-test with tasks related to the mutual positions of the lines and planes. The post-test was then evaluated and the results from both groups were compared in Table 2.
According to the values, we can see that success in solving problems is higher in the experimental group. These results are better in the range of 10% to almost 30% compared to the control group, which is not negligible. Only for comparison, the results of the pre-test in both groups varied from 1% to less than 5%.
At the end, we can conclude that the mind maps in our presentation with our teaching are more effective compared to the traditional classical teaching method.

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