THE PODKARPACIE CENTRE FOR TEACHER EDUCATION IN RZESZÓW

Modern Methods of Teaching – Learning Mathematics and Related Subjects

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Nowadays knowledge allows you to live a couple of years at the most,
whereas the method of acquiring it – entire lifetime.
J. Andrzejewska

Introduction

Teaching Mathematics and Natural Sciences is taking place in rapidly changing conditions. It is necessary to look for optimal didactic and educational solutions encompassing goals and contents as well as forms and teaching methods allowing for preparing students to face the challenges of the contemporary world.

The most significant role of educational system in terms of teaching Mathematics and Natural Sciences is developing and promoting subject competences as an important factor fostering student's personal development and the development of society. Well organised mathematical and natural sciences education facilitates logical thinking and expressing ideas, organizing own work, planning and organizing the learning process, collaboration and responsibility; it prepares for life in a modern world and enables to perform many jobs. The teacher is required to pay more attention to students' awareness of developing learning skills and study habits, recognizing and analysing problems and predicting solutions to them. Undeniably, the implementation of modern teaching methods and techniques enhances students' curiosity about Mathematics and Natural Sciences and increases their understanding of the basis of mathematical and scientific knowledge. In accordance with the trends teaching Mathematics and Natural Sciences is supposed to help students understand and solve everyday problems.

The aim of this publication is not only to present and depict active methods, but also to confirm that they encourage contemporary students to work in class, acquire knowledge and skills that are necessary in life. Moreover, the results of the research are to show how teachers applying active methods assess the effectiveness of their work and how students respond to this way of teaching.

I. Teaching Mathematics and Natural Sciences

On account of social changes towards the knowledge society and new educational needs relating to strategies, methods and techniques for teaching Mathematics and Natural Sciences, new pedagogical trends appear, promoting "learning by doing, experiencing and communicating". The abovementioned relies on four educational and tutorial pillars: to know what, to know why, to know how and to know who.

Knowledge should fulfil four basic functions:

– activating function – i.e. stimulating previously acquired knowledge in order to broaden it,

- triggering function – i.e. stimulating the acquisition of new information via coming up with new ideas,
- practical function – i.e. defining means of performing actions and activities,
- educational function – i.e. enhancing positive emotions, creating attitudes and increasing motivation.

Knowledge should be perceived as a process not a product. Today, students are constructing mathematical and scientific knowledge. The educational perspective has been changed – from focusing on thoroughly prearranged tasks, which must be completed by students, to concentrating on a learning process and students' previous educational experience.

Modern teaching requires transition from teacher's subjectivity to that of a student. Transmitting subject knowledge, teachers provide students with creative and critical thinking skills, which consequently let them develop the skill of self-development. Teacher's role is to enhance students' knowledge and skills acquisition in new situations. The process of learning and self-improvement should rely on students' understanding the structure, functions and integration of the brain, sensory preferences, differences in functioning brain hemispheres, brain dominance profiles, learning styles, copying with stress, and the different types of memory.

As far as new educational solutions are concerned, learning strategies facilitating the acquisition of students' knowledge by means of solving theoretical and practical problems are brought to the fore. They comprise practical and intellectual actions as well as the ones that facilitate emotional development, i.e. learning by doing (situation-based learning), learning by communicating (problem-based learning) and experiential learning (simulations, creative thinking techniques, techniques facilitating critical thinking and asking questions).

They include:

1. **Situation-based learning**

Situation-based learning relies on context and refers to particular situations that require acting, decision-making and communicating. Teaching is treated as a social process, during which knowledge is built collectively by a student and a teacher. Knowledge must be contextual and refer to particular situations, whereas learning must take place in a particular social environment.

Frequently, while applying situation-based learning teachers make use of a **task-based strategy**.

Depending on a trained skill, one out of five types of tasks controlling different fields of knowledge can be chosen:

- theoretical tasks, which aim at monitoring and evaluating integrated tasks,

– control-oriented tasks and tasks evaluating the degree of knowledge and skills acquisition concerning planning, predicting results, undertaking theoretical and practical tasks,

– corrective tasks, aiming at correcting and controlling task situation,

– decision-making tasks, requiring from students the skill of solving problems in a particular situation, relying on previously acquired knowledge,

– tasks controlling and evaluating the skill of communicating in different situations.

2. Problem-based Learning

Modern problem-based learning neither rely on arranging problem situations, so called pseudo problems (after all each difficulty is a problem), nor on tasks which do not require creative thinking, asking questions, answers to which can be found in a course book as well as wrongly formulated questions, unclear or including the answer. If this were the case, the teacher would seem to be the only person in the class who has a problem to solve, while students would easily get accustomed to apparent participation in a lesson.

Problem-based Learning relies on the following: organizing problem situations, depicting problems, providing students with indispensable assistance in solving problems and in this way checking solutions, managing the process of systematizing and reinforcing the required knowledge.

A problem situation occurs when we know what we want to achieve, but we do not know how to do it. In turn, **a problem task** appears if there is no algorithm (an explicit and reliable instruction composed of the finite sequence of operations, that is necessary to be performed to achieve a particular goal).

Didactic problem is a theoretical or practical difficulty, the solution to which students owe to their own research. The following types of problems can be identified:

- indicative problems (cognitive) – decision-making (requiring making a decision) – executive (requiring taking actions),
- open problems – closed (having the set of possible solutions),
- convergent problems (having one solution) – divergent (having many solutions).

The stages of Problem-based Learning:

- creating a problem situation,
- eliciting and defining a general problem,
- identifying specific problems,
- putting forward and confirming hypotheses,
- establishing the means of solving specific and general problems,

- verifying hypotheses in practice,
- drawing conclusions and solving a problem.

In practical terms the problem-solving method may take the form of:

A discovery method is used by teachers while solving mathematical and scientific subject problems. It involves actions which aim at revealing and naming relations between phenomena by means of laws and rules. While solving problems by a discovery method, students develop learning skills and learn to apply acquired knowledge by analysing real situations.

A discovery method relies on a mental process of innovativeness or inventiveness. Searching for new solutions, students should follow the path of an innovator. This method is applied to raise students' awareness of the shortcomings or flaws of an object, so that they are forced to look for improvements by eliminating deficiencies and discovering a rule which allows for finding a new solution.

Action planning method is used for solving technological, production, economic and structural problems. It follows the subsequent stages:

- becoming aware of necessary actions in a particular situation,
- identifying the main task, needed to carry out to achieve the objective, a detailed analysis of the present and desired situation, developing a solution and valuing different projects,
- preparing and implementing a new action plan.

3. Learning by doing, experiencing and communicating

The choice of a teaching strategy depends on whether we want students to come up with their own new ideas (learning by doing) and confront them with their experience or a situation (experiential learning) or to accept a controversial idea (learning by communicating).

Learning by doing, experiencing and communicating lays the basis for the research-oriented attitude of students and conditions the development of skills in terms of: putting forward and verifying hypotheses concerning natural phenomena and processes, practical application of knowledge, observations, measurements and experiments, as well as broadening the knowledge of the methodology of Natural Sciences. The acquisition of the abovementioned competences is defined by educational objectives and goals.

Learning by doing, experiencing and communicating can be applied in everyday situations, in which students deal with own tasks and projects. As far as advantages of this practical method are concerned, the most crucial ones are facing real life challenges that every person has to cope with, as well as developing social skills and dealing with changes.

In this strategy scientific thinking, scientific reasoning and scientific competences of learners play a crucial role.

Scientific thinking is an ability of applying scientific knowledge to identify and solve problems as well as drawing conclusions based on empirical observations of nature and society.

Scientific reasoning refers to understanding characteristic scientific procedures (a sort of mental activity), methods and tools thanks to which scientific research is conducted and conclusions are drawn, e.g. distinguishing between information based on facts or scientific evidence and information including opinions or assumptions.

Induction (inferring general conclusions on the basis of observations) and **deduction** (inferring the specific from the general) constitute the starting point for reasoning.

Scientific competences refer to abilities and willingness to employ knowledge and methodology for explaining phenomena in order to formulate questions and draw evidence-based conclusions.

4. Action teaching

The overall aim of this method is **to gain operational knowledge by a student** through a well-planned set of actions. Students construct their knowledge integrating it with materials and various tasks through the prism of their experience.

Action teaching is a strategy of a teaching-learning process rooted in Piaget's theory of cognitive development, applied mainly in teaching Mathematics. It aims at gaining operational knowledge not merely by means of chaotic attempts of solving mathematical problems, but via pre-planned by a teacher student's actions. The tasks shall be selected in such a way that enables students' transition from concrete operations, through symbolic to abstract ones. A thorough analysis of operations within concepts, which must be acquired by students, is the starting point for planning and selecting tasks. Thus, as the designer and promoter of this strategy in Poland – Zofia Krygowska claims, there are two basic teaching principles that the teacher is required to implement:

1. By means of a analysis extracting from a subject matter basic operations within each definition, theorem and proof.
2. Creating problem situations that enhance interiorization and student's mathematical thinking as a specific and conscious use of gradually adopted operations. Moreover, the consistent application of didactic processes aims at ensuring the accuracy and effectiveness of this process. While developing the understanding of concepts, it is necessary to plan the didactic process properly, so that enactive representations will result from specific actions, iconic representations will stem from symbolic operations and symbolic representations will derive from abstract operations.

The trial and error method, a spontaneous, intuition-based means of dealing with tasks and solving problems, can be an element of action teaching. This involves performing

seemingly chaotic actions (for these who are used to applying schemes and analogies), until a desired result is achieved.

The trial and error method constitutes the basis for many other methods which lead to discoveries and solving problems.

In Mathematics it is called a method of successive approximations, i.e. rethinking and searching for something new and good. That is why it develops critical thinking, creativity, originality and resourcefulness of students.

5. Anticipating education

Anticipating education relies on the assumptions of constructivist learning theory: from references to students' prior knowledge (most often common-sense knowledge, but also semantic one) or external sources, through processing to systematization so as to finally with the assistance of the teacher build learner's system of categories.

The essence of anticipating education involves learners' active organizing and acquiring knowledge before the lesson during individual collecting information as well as searching for references in own prior knowledge concerning the subject matter, which is finally discussed during the lesson. In order to gain preliminary, general or psychological understanding of new material, students use existing knowledge, experience, assumptions, emotional-cognitive relations, common-sense knowledge or even semantic knowledge. They search memory for information and experience which will allow them to understand and personalize new material. Only after developing an overall picture of the planned topic, a directed action takes place in accordance with the tasks that are precisely defined by the teacher. A prepared in such a way learner, comes to the class to present his/her knowledge to the teacher, whose role is to inspire the learner to systemize acquired information. It is learner's self-assessment that primarily finalizes the whole process. Students are familiarized with tasks before a lesson, which directs learners' thinking not towards the material presented by a sender-teacher, but towards self-gathering and organizing information, in other words mental processing of acquired information. In this way new information is/can be actively associated with the one stored in memory. According to Jean Piaget two processes occur here – accommodation and assimilation. The existing schema is/ can be accommodated, and the new one assimilated. In this way the essential lesson is the response to anticipatory operations. In this type of learning students are first of all inspired to build a bridge between the existing schema, common-sense knowledge as well as experience and information that they are supposed to acquire. (Kruszewski, 2004) Anticipating education, as suggested by the authors, may seem to be useful for building such a bridge. It assumes that school education falls into three stages:

- looking for references in existing schemata and external sources,
- information processing,
- systematization and categorization.

Actually, students gather information, organize it and then build their personal subject knowledge via constructing contents, performing tasks, so as to finally with the help of the

teacher systemize the acquired knowledge. While performing tasks connected with the upcoming lesson, learners first of all make use of the abovementioned tools. They also use them while communicating with a teacher.

Anticipating education takes place in stages. Each stage is connected with particular actions aiming at attaining desired goals.

Activation

Activating students, their common-sense knowledge about objects, phenomena and problems takes place at this stage. Learners reflect themselves as well as with the aid of a teacher (teacher-directed reflection) on the subject matter of the lesson. Activating prior knowledge of the subject matter is the core of students' actions at this stage. Teacher's role is to support and encourage learners' creative thinking, to inspire the creation of personal information concerning the subject matter, based on various sources, own thoughts and judgements.

Processing

This is the stage at which learners perform particular tasks connected with the subject matter, using various educational materials. Students work individually and in groups, communicating with one another and with a teacher, and tend to collate and sort out collected material. At this stage it is crucial to use such mental processes as: analysis, synthesis, generalization, making comparisons, defining and reasoning (proving, explaining, concluding).

Systematization

This stage takes place during the lesson at the presence of the teacher. At this stage students systematize information acquired while answering questions and solving problems. They develop the awareness of personal cognitive constructs and incorporate them into a scientific categories system, in accordance with a defined and selected by a teacher category of educational goals. Categories are also specified in terms of pragmatic thinking. What? In which context...? Why and how? With what results...?

Evaluation

Students deal with acquired knowledge at this stage. They act as critics, reviewers, making statements concerning their work and achievements, what has changed in their knowledge since they started dealing with the subject matter, what can be added, how it can be organized better.

Teacher's task is to evaluate students' work on the basis of collaboratively elaborated with them criteria.

This stage is to shape students' belief that answers to questions always arise new questions, that knowledge is never final, that it has a temporary and existential dimension.

The elements of verification and evaluation appear at each stage of the anticipating strategy.

Depending on the evaluator, there can be distinguished:

- **Self-assessment** – the act of evaluation which shifts the focus from external control to self-control.
- **Peer-assessment** – the act of evaluation during which a learner collaborating with the group or presenting the output of his work in front of peers receives feedback from them, which has a formative character.

With regard to the subject of correction and evaluation there can be distinguished:

- **Student's source-based work assessment** – the anticipating education strategy is largely based on students' personal engagement in diverse information source-based work. Learner's work results are placed in an electronic portfolio and are presented in the class to all participants of the lesson. In this case the subject of evaluation can be the analysis of source texts, distinguishing the relevant information from the less important one, or verification of the reliability of sources. Consideration may also be given to self-reliance in dealing with issues. After all, interpreting information is different from copying it.
- **Student's work assessment** – frequently material works, such as posters, projects, e.g. connected with survey research and its analysis or a social campaign are the results of tasks performed within the anticipating strategy. The originality of students' works, reliability, honesty in research, etc. can be the subject of evaluation.
- **Student's involvement evaluation** – e-learning requires considerable commitment from students, manifested by activity in chat rooms and internet forums likewise during lessons, when numerous discussions take place. In this case, learner's activity, the content of statements, the ability of providing arguments based on facts and distinguishing them from judgements will be the subject of assessment.
- **Student's knowledge assessment** – tests measuring students' knowledge connected with the current subject matter.

II. Teaching methods and learning strategies based on experience – Kolb's cycle

What I hear, I forget.

What I hear and see, I remember a little.

What I hear, see, and ask questions about or discuss with someone else, I begin to understand.

What I hear, see, discuss and do, I acquire knowledge and skill.

What I teach to another, I master.

Mel Silberman

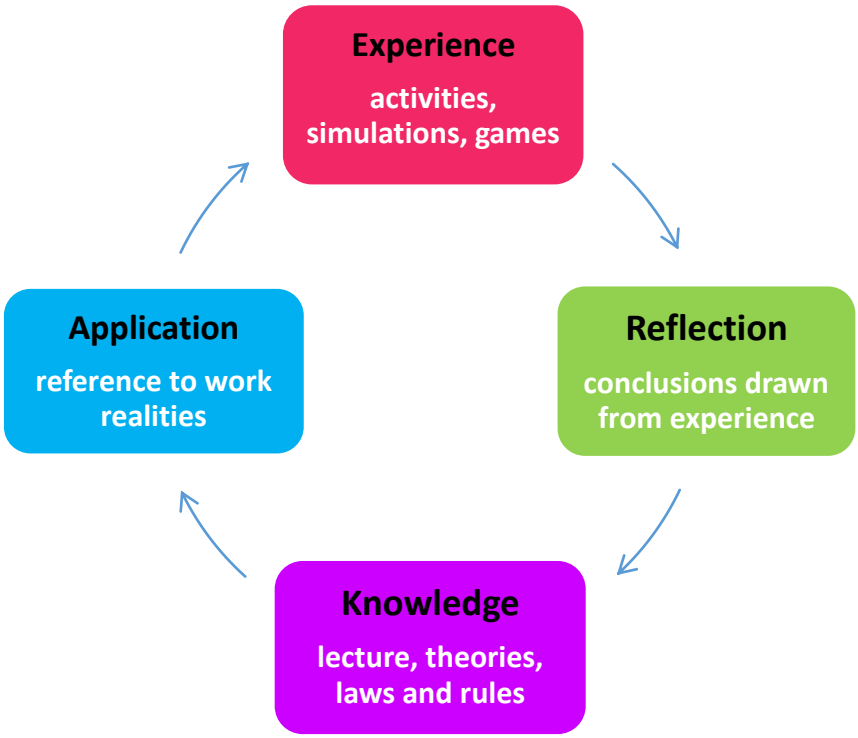
The role of the teacher is to create educational situations enhancing the process of learning and to monitor this process.

Kolb's Experiential Learning Cycle is a universal method of designing an effective didactic process.

Kolb's model, among others, is based on experience and practical application of knowledge and skills. Learning by experience does not begin by getting familiarized with the sequenced set of principles, concepts and rules, as in the traditional way of learning, but it starts with specific experiences or activities that are observed; and on their basis reflections are provided, and additionally, concepts and principles suitable for use in different situations are formed.

Kolb's Experiential Learning Cycle is a four-stage process and falls into:

1. **Gaining concrete experience** through activities, by performing individually and in small groups different real tasks.
2. **Reflective observation**, i.e. self-reflection and a group discussion about a performer, a task or an activity as well as expressing opinions and feelings.
3. **Abstract conceptualization:** gaining theoretical knowledge, formulating ideas and rules, familiarizing with background information connected with a task or an activity.
4. **Active experimentation**, i.e. testing personal theories and concepts in various conditions, applying acquired skills at work and in everyday life, as well as defining own needs in terms of anticipated experience.



Experiential Learning Model

Experiential Learning is based on three assumptions:

1. We learn best if we are personally involved through our actions and emotions in an educational situation.

2. We learn best if we are allowed to set ourselves educational goals and preserve the freedom of achieving them within established limits.

3. Experiential learning is a process of generalizing own experiences and drawing conclusions from them. It engages an individual in learning and requires taking partial responsibility for systematizing conclusions drawn from experience.

The effectiveness of learning through experience is conditioned by:

1. following the whole learning cycle,
2. taking into account various individual learning styles and pace,
3. different approaches to the role of a teacher and a student:
    - teacher's deeper understanding of students and establishing emotional contact with them, holistic approach to students, developing closer relations and emotional bonds with students,
    - creating the atmosphere of collaboration, acceptance, trust and mutual support,
    - establishing rules with students to make group work efficient, and to allow students to take responsibility for their own choices and effective communication with others,

- while assessing, paying attention to the positive reinforcement as a significant element of developing proper self-esteem,
- introducing the elements of fun and humour which activate and improve concentration and group integration.

Application of active methods is supposed to foster student's independence and master learning skills.

Students should take on some responsibility for their own learning, understand their own needs in terms of learning, know own learning styles and their advantages and disadvantages as well as refer acquired knowledge to themselves and their situation.

The teacher should be a guide, a leader, an animator of learners. He should watch the dynamics of group work – organize group work, assign tasks for groups and be able to use all the resources and skills. He shouldn't assume the role of „an expert", but should possess communication skills, create the atmosphere of safety, be able to maintain a balance between the established program and participants' needs as well as between the needs of the group and its individual members.

As far as the experience-based model of teaching and learning is concerned, teachers often use a variety of active methods, allowing for the effective implementation of mathematical and natural sciences contents in junior school.

The following methods are applied in experiential learning:

- **Problem-solving methods**, which enhance developing critical thinking, rely on presenting to students problem situations and organizing a cognitive process. For that purpose various sources of information are used, e.g. educational films, photos, drawings, the Internet or figures. Cognitive and educational processes, occurring then, comprise analysis, explanation, evaluation, making comparisons and concluding. Some exemplary methods are: brainstorming, an observation, a panel discussion, a problem-solving method and a case study.
- **Methods of impression and expression** focus on emotions and experience. They facilitate students' emotional engagement. This is the result of sensations and experiences related to the performance of particular tasks (e.g. educational games). Some exemplary methods are: drama technique, simulation, mind mapping, laboratory work or project.
- **Visualization methods**, by means of which a decision making process is presented by a diagram or a drawing. They encourage independent decision-making. Some exemplary methods are: a decision tree, fishbone, a poster, mind mapping, snowballing, and an association map.
- **Operative teaching techniques**, such as map reading, the analysis of statistics, graphs, charts and diagrams are widely used by teachers.
- **Exposing methods** are the ones which rely on exhibiting natural specimens and are essential for teaching complicated natural sciences issues.

III. Characteristics of the selected teaching methods in Mathematics and Natural Sciences

III.1 Strategies for managing students' independent work

- **Educational games**
- **Panel discussion**
- **Delphi method**
- **Morphological analysis**
- **JIGSAW**

EDUCATIONAL GAMES include the elements of situation-based teaching, panel discussion, simulation, drama, etc. Using games prepares students for performing different social roles, leads to a better understanding of environmental phenomena and facilitates the analysis of various situations.

PANEL DISCUSSION requires roles allocation. Individual students take on assigned roles and act as experts, scientists or the representatives of various professions. Lesson's topic is set beforehand and students prepare their presentations, collect necessary materials and arguments before the discussion starts. The teacher reminds the motion of the discussion and theses, sets time limits and gives debaters the floor. Discussion participants express their views, polemize with experts' statements presenting their arguments and counterarguments. The appointed earlier team of independent judges analyses facts and opinions cited by the panellists and demands additional expert reports and clarifications in order to finally formulate a statement. Information and knowledge integration takes place and new problems emerge which requires further analysis and solutions, either as part of homework or during the next lesson.

DELPHI METHOD uses an indirect form of expressing opinions by experts, whose task is to respond to special questionnaires including subject matter questions. The Delphi method deals with a hypothetical course of future events.

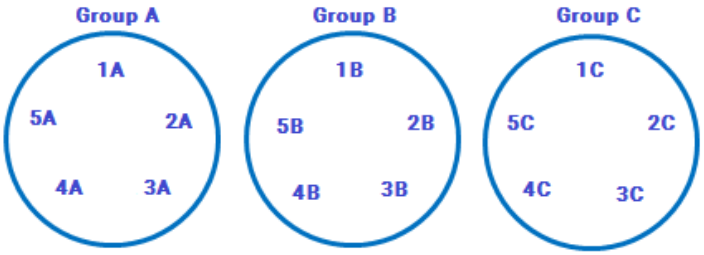
MORPHOLOGICAL ANALYSIS is understood as any attempt to arrange a system with regard to its components or a form. At the beginning it is necessary to make a list of possible aspects, which may determine the problem. Preferably there should be applied a two or three-aspect morphological analysis of the problem. In turn, the list of attributes determining particular aspects is created. Next diverse connections between attributes are analysed and the most interesting ideas, e.g. a wood-colour round watch, are explored. Then the ideas are evaluated in terms of their suitability.

JIGSAW is a cooperative learning technique. This method has a universal character and can be successfully used for teaching different subjects. It aims at involving students in the

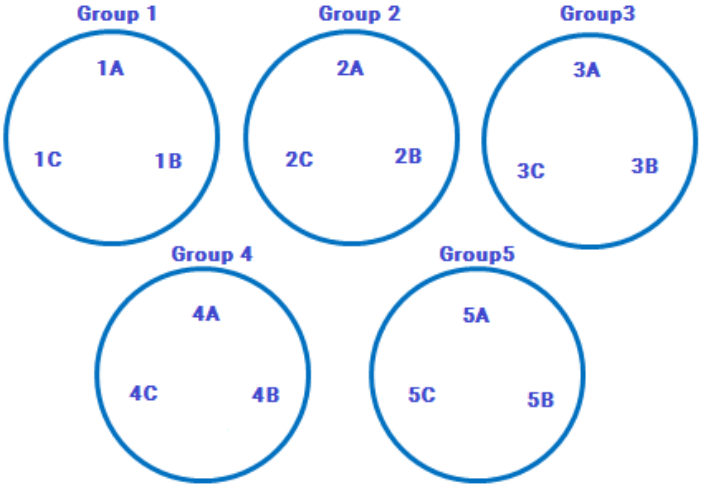
learning process. It promotes in-depth learning by making students responsible for teaching some part of material to their classmates. JIGSAW technique is used when students have to acquire some contents, which can be divided into coherent pieces that compose a jigsaw-like structure. All the students are to achieve progress in accordance with the principle that the best way of learning is teaching. Just as in a jigsaw puzzle, each element – each learner's part is crucial for the completion of the final product, i.e. the final results of all the students.

JIGSAW falls into the following stages:

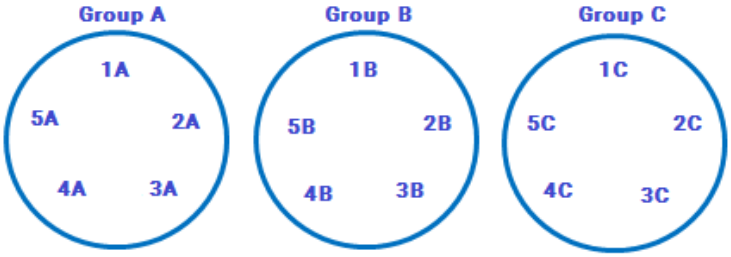
- **I stage** – personal learning – each participant in the group receives a different text to read and analyse



- **II stage** – consolidation, explanation; experts
-



- **III stage** – learning (groups as in the first stage)



- **IV stage** – subject knowledge testing

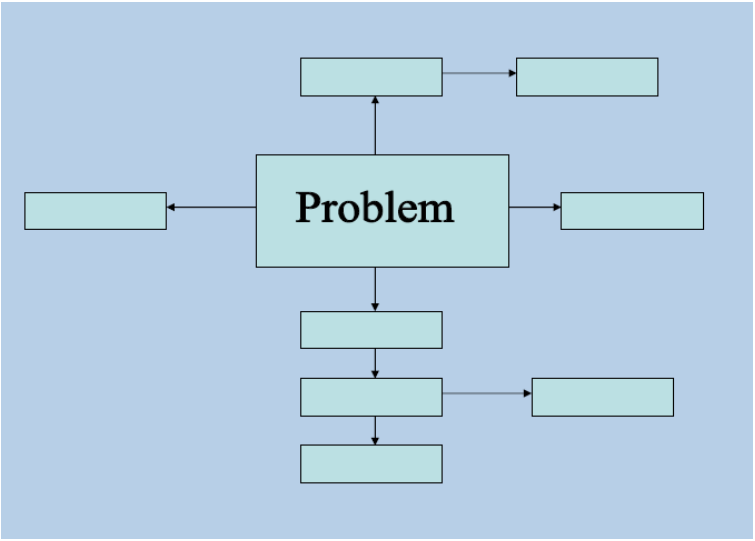
III.2 Methods for creating and defining ideas

- **Timelines**
- **Chain association**
- **Mental mapping**
- **Information window**

TIMELINES is a method of a visual representation of the problem in a chronological order. It shows a linear course of events and the sequence of time. Time spans, facts and the subject matter of the lesson are marked on long strips of paper.

CHAIN ASSOCIATION has a form of a note written on an A2 or A4 sheet. Learners receive a chain made up of empty links, which they fill in with terms, they have learnt during the lesson, as well as with associations fitted to the subject matter context.

MIND MAPPING – is used for visualising an idea, a term, a problem or a phenomenon, etc. Divided into groups, learners receive large sheets of paper. In the middle of the poster they write down a term, which is a subject of associations. They can illustrate it. The teacher explains the idea of mind mapping and presents a diagram. Students' task is to draw a similar map for a given word. Having finished the task, students present their maps, and on their basis they jointly formulate a definition.

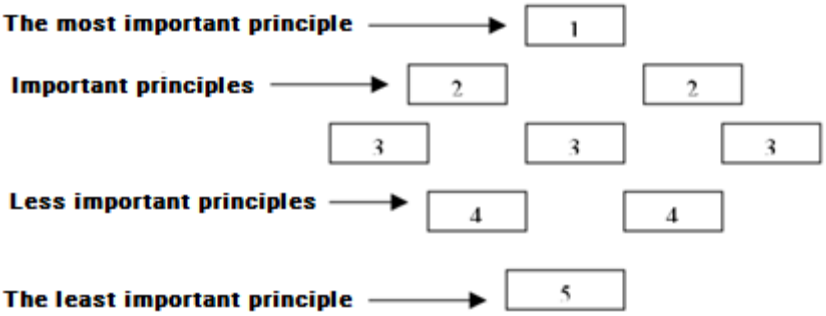


INFORMATION WINDOW is a form of creative note. A sheet of paper is divided into four parts (horizontally, vertically or diagonally). In the first window the term of concern is written down. In the second window the definition of the term is placed (from a lexicon or provided by students, etc.). Metaphorical meaning of the word is written in the third window (a joke, a rebus, etc.). The fourth window can have a form of a comic, a dialogue or a caricature referring to a given word.

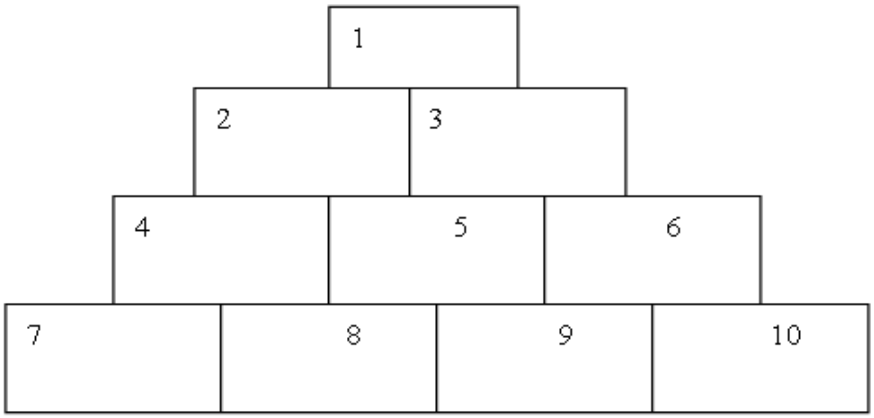
III.3 Hierarchical methods

- **Diamond ranking**
- **Priority pyramid**
- **Criteria poker**
- **Learning priorities**

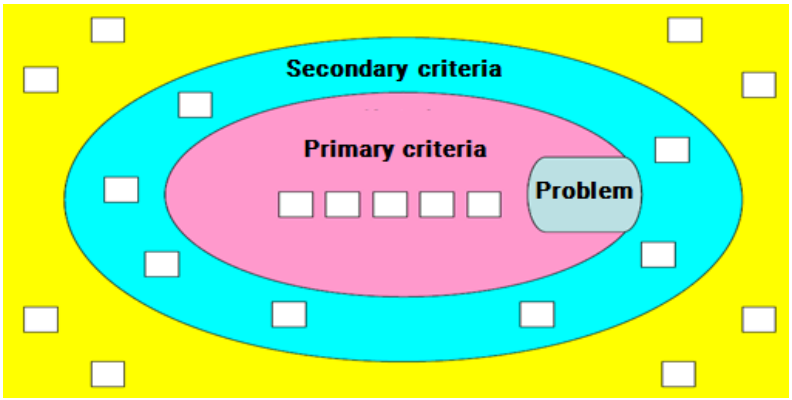
DIAMOND RANKING – this technique is also known as „diamonds". The arrangement of principles resembles the shape of a diamond or „diamonds".



PRIORITY PYRAMID – this technique aims at making a list of principles in accordance with pre-set criteria, e.g. the criterion of importance or order criterion. During a brainstorming session students put forward subject matter ideas. They work in groups. Each group is given sticky notes and a poster with a pyramid. Students choose ten most important phrases and write them down on sticky notes. Then they stick them on the priority pyramid, matching a given criteria. Having completed the task, they make a collective class pyramid.



CRITERIA POKER is a board game. The teacher prepares a poker board with an inscribed standard and spaces for the primary, secondary and tertiary criteria, and then distributes cards with criteria. Students compete with each in accordance with the established in advance rules, which should be written on a poster and hung in the classroom.



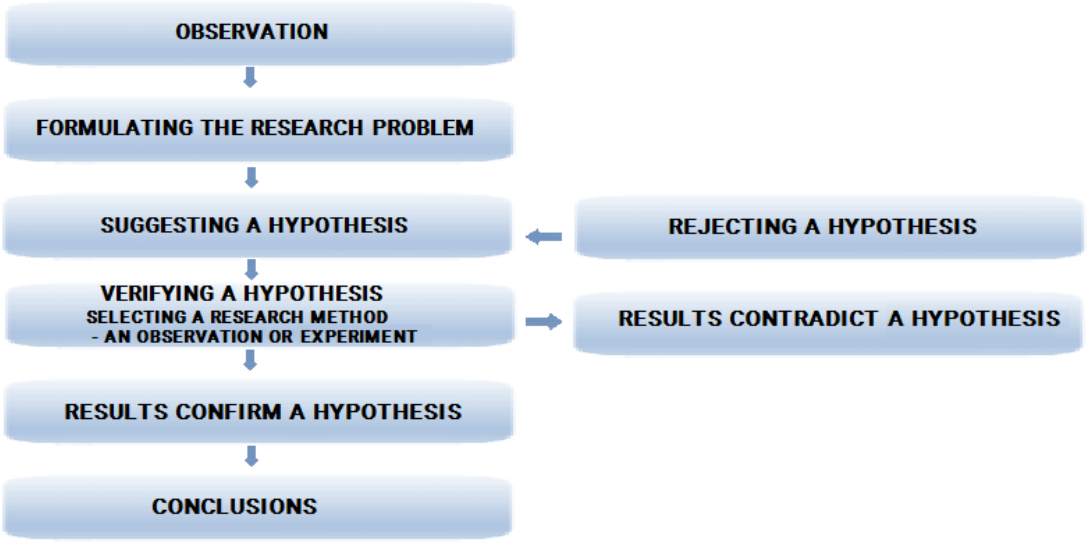
LEARNING PRIORITIES – The teacher familiarize learners with a topic – the subject of evaluation. Working in groups, students define the lists of specific subjects, which according to them are related to the main issue. They write them down on the poster. Then the groups present their posters, and individual students by means of self-adhesive price labels (e.g. 3 per student) mark their priority issues or the ones they would like to deal with. The procedure of counting points up is followed by the obligatory ranking of issues. This method can be used at the beginning of the school year for planning the course and the content of lessons.

III.4 Creative problem solving techniques

- **Laboratory work**
- **Triangle method**
- **Six thinking hats**
- **6-3-5 Brainwriting**

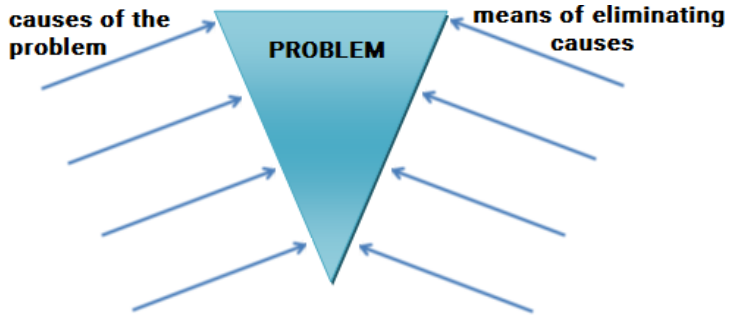
LABORATORY WORK falls into three phases: preparatory, implementation and control. During the first phase it is necessary to prepare adequate materials and teaching aids, indispensable for proposed activities. It is essential to carry out preliminary observations and experiments, as well as prepare the instructions to follow. Conducting observations and experiments should result from emerged problems and formulated hypotheses that occurred on the previous or present lesson. The instruction should have a form of a reasonably set sequence of activities to be performed. Laboratory method requires formulating experiment objectives and a research problem, putting forward a hypothesis, conducting the experiment, presenting results, drawing conclusions and confirming or rejecting a hypothesis.

Research procedure:



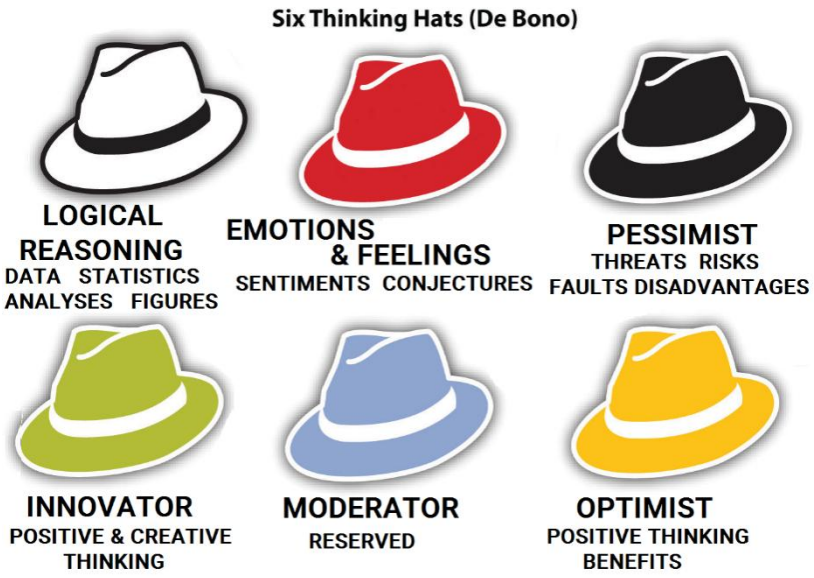
TRIANGLE METHOD is used for the purpose of a creative problem solving**.** An inverted triangle symbolizes a problem. On one side it has the causes – supporting force, and on the opposite side it has the means of eliminating the causes – inhibiting force. The method involves defining the causes and looking for solutions to the problem.

The teacher distributes the sheets of paper, on which students write down what helps or disturbs them during the lesson. Students read out their points and the teacher writes them down on the board, ticking out the ones which are repeated. By means of "price labels" students mark the prevalent causes, the ones that disturb them to learn. The teacher divides the class into groups. Each group is given a poster with an inverted triangle into which one of the problems is written down. Then the students analyse the factors which pose the problem and write them on the left side of the triangle. Next the students consider the ways of eliminating destructive factors and write them on the right side of the triangle. The groups choose their representatives who present problems and discuss solutions to them.



SIX THINKING HATS – this method is particularly useful when students are expected to cooperate with each other and in accordance with their predispositions

participate in solving problems. The teacher prepares six different coloured hats and informs students that each hat identifies one of six modes of thinking.



White hat – facts, figures, the measured and the proved, source-based information, analyses outputs and statistic data.

Black hat – a pessimist who can see threats, shortages and dangers of a suggested solution; criticism, precaution, taking a black view of things.

Red hat – emotions, gut reactions.

Blue hat – analysing processes; a conductor, a chairman who presides a meeting, gives a voice to discussion participants, sums up a debate.

Green hat – opportunities; an innovator, a creative person.

Yellow hat – optimism; seeing the word through rose-coloured glasses, noticing advantages and benefits of a solution, positive thinking.

6-3-5 BRAINWRITING is a technique that involves groups of 6 persons who are required to write down 3 solutions to a problem on special worksheets which are passed to a person on the left. The procedure is repeated 5 times.

The teacher divides the class into 6 groups. Each of them receives worksheets. The teacher presents the problem. The task of the groups is to find three solutions to the problem and write them down into the numbered blanks.

When the teacher says „start", students pass worksheets clockwise. Groups read the ideas written down by the previous groups. They fill in the blanks with three own ideas, trying not to repeat formerly written ones. The swap of worksheets occurs 5 times. Having accomplished the task, students present completed worksheets. They evaluate ideas and select the achievable ones.

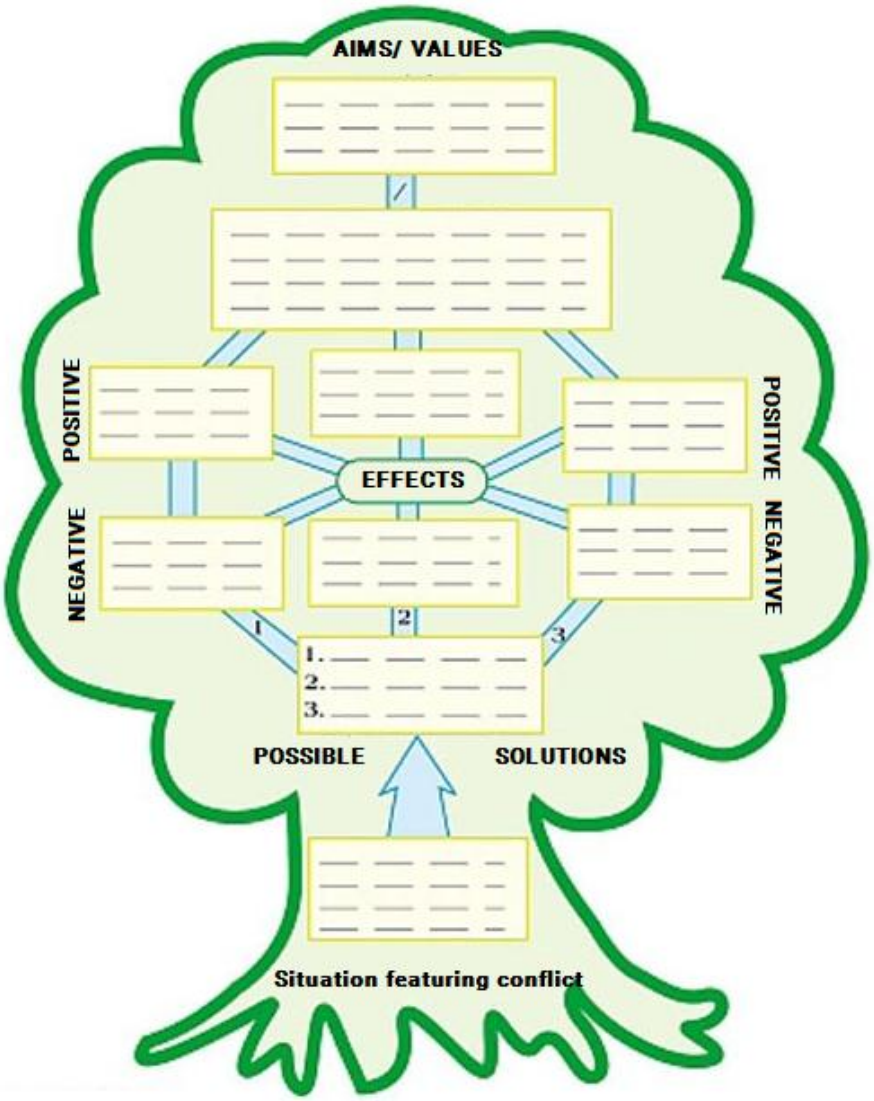
	PROBLEM:		
1 student	1	2	3
2 student	1	2	3
3 student	1	2	3
4 student	1	2	3
5 student	1	2	3
6 student	1	2	3

III.5 Effective argumentation and stating opinions techniques

- **Brainstorming**
- **Decision tree**
- **Fishbone diagram**
- **Discussion**
- **Talking-point discussion**
- **Snowballing**
- **Debate**
- **For and against debate**
- **Fishbowl**
- **Carpet of ideas**
- **Metaplan technique**
- **SWOT analysis**
- **Sustainability compass**
- **Modelling-based learning**
- **Case-based learning**
- **Situation-based method**

BRAINSTORMING, also called **IDEAS EXCHANGE**, requires group work and relies on generating as many new and sometimes astonishing ideas as possible as well as on providing solutions to problems. It creates the sense of freedom and competition. When all possible ideas are collected, evaluation takes place.

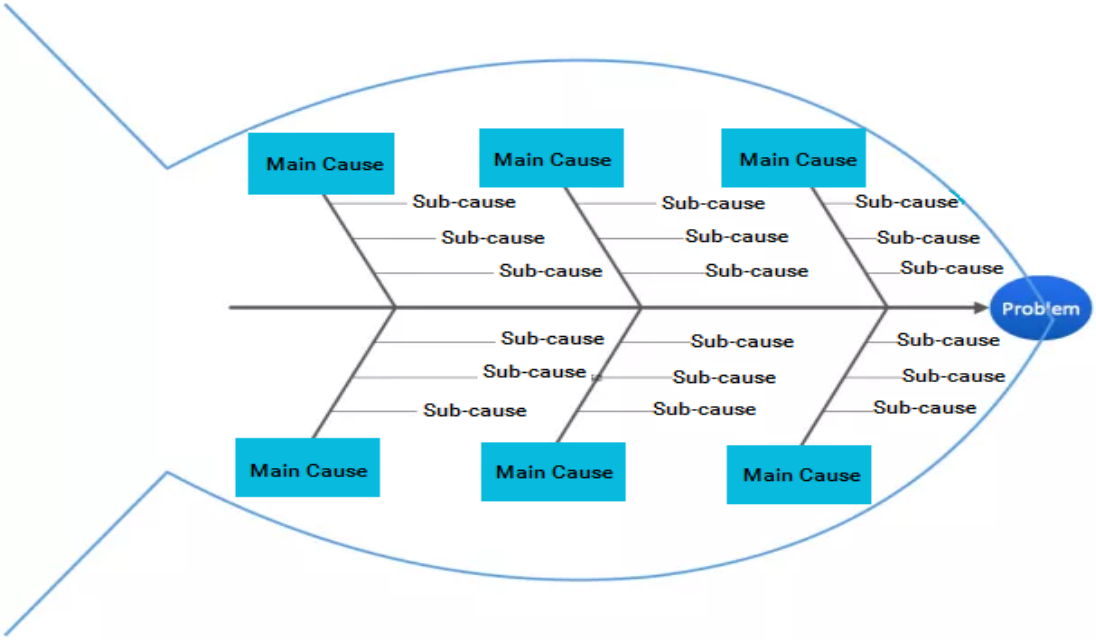
DECISION TREE is a technique which makes use of a tree-like graph with a decision analysis displayed. The problem and possible solutions to it have to be written down respectively in the "trunk" of the tree and on the level of its branches. The positive and negative consequences of particular solutions are gathered on the third level. The aims and values taken into account by decision-makers should be defined in the „crown" of the tree.



A simplified decision tree:

Question or problem:			
YES		**NO**	
Benefits	**Dangers**	**Benefits**	**Dangers**
Your decision:			

FISHBONE DIAGRAM– this method is used for identifying problem generating factors. The poster of the fishbone model should be prepared. The problem is written down in the „head" of a skeleton. Brainstorming, students identify main causes and write them down into relevant boxes at the top of "the big fishbone". The number of groups equals the number of „big fish bones". Each group has one "fish bone" and is responsible for identifying the origins of a main cause, i.e. sub-causes. Next the representatives of each group write them down into sub-causes gaps and out of the gathered data indicate the most significant ones. They draw conclusions and the problem is solved. It is required to set time limits for performing the task.



A DISCUSSION is simply an exchange of views, arguments, opinions and assessments concerning a particular subject matter. It is carried out in several stages:

1. **Initial stage** – clarifying the theme and purpose, setting time limits and rules.
2. **Development stage** – admitting free discussion.
3. **Arrangement stage** – proposing partial themes and steps, „throwing a ball" and passing it, ensuring the principal theme and summing up subsequent stages of the discussion.
4. **Final stage** – enumerating and connecting discussed items as well as summarizing the discussion.

A discussion will allow for learning about students' attitudes to a problem and different points of view, but it does not have to lead to one solution. While organizing a discussion, it is worthy to exploit the following techniques: challenging the facts technique, giving examples, making comparisons, boomerang strategy, joke strategy, scoffers' loge and sycophant's' loge.

TALKING POINT DISCUSSION – Students have a discussion in groups of 6-8 people, while the other students and the teacher listen to them. The discussion lasts from 8 to 20 minutes, depending on the subject and the age of students. Participants use a discussion plan so as not to stray from the subject matter. Each time students take the floor they can score or lose points, which is recorded on a previously prepared score sheet.

Students score points for:

- taking a stand on the issue,
- presenting factual information or information obtained by means of a research,
- making relevant comments,
- encouraging other students to join the discussion.

Students may lose points for:

- interrupting, disturbing,
- monopolizing the discussion,
- personal attacks,
- making irrelevant comments.

Monopolizing the discussion by one student is the most serious offense, as the others cannot join the discussion and lose the opportunity to gain points. The perspective of losing a point makes a student more attentive and helps the teacher maintain discipline and capture the attention of other debaters. This method can be an alternative to a traditional revision. Its additional advantage is making students discuss in a polite manner, so as not to offend anyone as well as neither monopolize nor control the discussion.

SNOWBALLING is an organized whole-class discussion.

Working individually, each student prepares, usually in a written form, suggestions for solving a problem. In pairs students discuss their proposals and provide a single one. Then the

proposals are talked over in groups of four and a collaborative proposal is formulated. Similarly, students work in groups of eight and sixteen (half of the class). Finally, a common solution to the problem is agreed by the entire class. With regard to the nature of the described strategy, snowball is sometimes called a discussion.

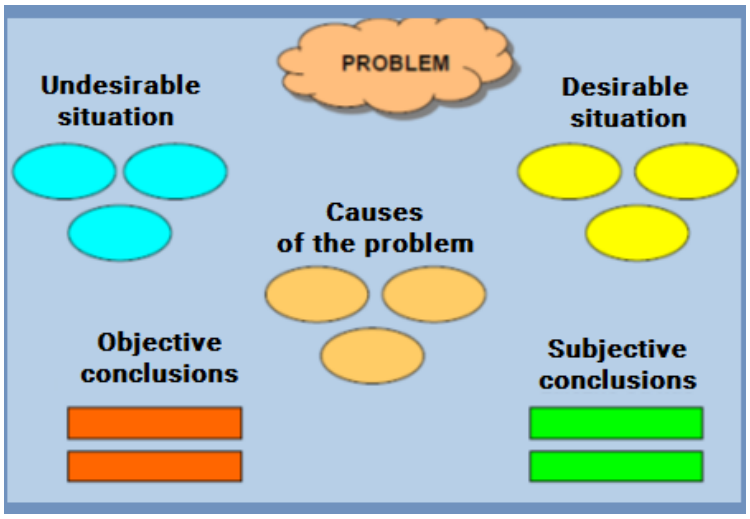
DEBATE – Working in two opposing groups, students respectively gather and discuss for and against arguments and write them down in a column.

FOR AND AGAINST DEBATE– this type of debate is applied if students are supposed to approach the problem from two different points of view, to analyse it and make a decision. This form of discussion develops the skills of logical thinking, argumentation and problem solving. It fosters searching for and organizing information, verifying own, often superficial, views, etc. The teacher chooses the topic, defines the rules of the debate, helps students to prepare for it and divides them into the supporters and opponents of the motion. The teacher listens carefully to students, but does not comment on their discussion. Debating parties present their arguments. Observers (on the basis of observation cards) or listeners (by means of voting) decide whose arguments were more convincing. For and against debate should be led by a chairperson, who is in charge of opening the debate, giving the floor or removing from the floor in case of accessing a time limit or violating the culture of a debate.

FISHBOWL – Characteristically for this type of a discussion, several participants sit in a circle, leading a conversation on a certain topic. The others, sitting around them, are observers and analyse the course of discussion in terms of arguments selection, efficiency of argumentation, respecting discussion principles and the overall course of the conversation. The objective of this discussion technique is primarily peer teaching and developing the skill of argumentation.

CARPET OF IDEAS is used for holding group discussions on a posed problem. Students write on cards possible solutions to a problem (one per card). Then they read them aloud and pin to the board, grouping the same or similar ones. When all the cards are pinned, a collaborative evaluation is made. Each student may give 1 point to the solution that is in his/her opinion the best one. The winning solution is the one that scores the greatest number of points. The final result can be discussed once again at the end of the activity.

METAPLAN TECHNIQUE is a graphic, poster-like way of holding discussion, either in small groups or larger ones. The discussion revolves around a specific topic, written on a coloured piece of paper in a "cloud" at the top of the poster. The participants write down their ideas in a short clear form, on a multi-coloured small pieces of paper of different shapes (oval, circle, rectangle), focusing on the analysis of the current state of knowledge on the subject matter (What is it like?), imagining an ideal state (What should it be like?) and wondering why it is not as it should be. Developing proposals for further improvement constitutes the summary of the discussion.



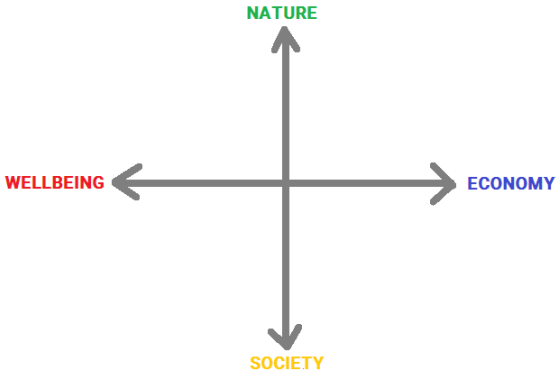
SWOT ANALYSIS aims at the analysis of the problem situation and developing possible solutions to it. At the initial stage of SWOT analysis it is required to provide the description of a current state of affairs, i.e. to establish what is satisfactory, what mistakes have been made or find out where shortcomings are. Consequently, it is necessary to look into the future and consider what should be changed and to what extent, and what threats may be posed concerning the proposed alterations.

As far as Natural Sciences are concerned, it can be used e.g. for extracurricular activities in chemistry, biology, physics, for instance with reference to the condition of natural environment in my city/town/village (or a selected component, such as the cleanliness of water, the air, a noise level). The application of SWOT analysis in the above-mentioned situation can be an interesting experience, as it is mainly used for resolving conflicts and social problems.

SUSTAINABILITY COMPASS is a technique which allows for developing the skills of diagnosing and thinking in terms of sustainable development.

The teacher draws a sustainability compass/ a compass rose and marks the directions: N is for NATURE, S is for SOCIETY, W is for WELL-BEING and E is for ECONOMY. Each vector is divided into 10 parts, which correspond to the maximum number of points for each field (assuming that there are 5 questions and 0-2 points can be scored for each).

Having prepared questions relating to each field, a diagnosis and an evaluation are made. Finally, the points are scored and scores are marked on each vector; then the marked points are joined. A model of a certain shape appears. The teacher and the group focus on the shortest vectors and try to find out the causes of such an undesirable situation. Then a recovery program is suggested.



MODELLING-BASED LEARNING exploits making, using and applying the models of organisms and their functions as well as the models of the interdependence of processes and phenomena during Natural Sciences lessons. Theoretical and experimental models are used in order to carry out experiments on them, to illustrate natural phenomena. The use of this method fosters developing the following skills: recognizing the need of modelling (structures, phenomena or interdependencies), constructing theoretical and physical models, presenting relations illustrated by means of models, perceiving analogies between models and structures, processes and phenomena, using the results of model analysis as a basis for formulating new hypotheses.

Making use of computer programs expands the possibilities of constructing models of different processes and simulating their course.

THE CASE-BASED METHOD is relatively simple. It involves a particular case analysis and problem solving in a small group of students. Having received a case description and a set of several questions to answer, the participants are given a few minutes to frame questions concerning the case, and the teacher is supposed to answer them. The solution does not have to be obvious. Quite often a number of possible solutions is accepted, but then students may demand explanations.

THE SITUATION-BASED METHOD is similar to the case-based method. Students are involved in a complex set of circumstances, which combines problem solving by means of discussing for and against arguments. Students have to understand the situation and make a decision in order to find a solution to the problem, and then predict the consequences of this decision and any other decisions. The implementation of this method is difficult, as it requires the preparation of descriptions, tables, diagrams, etc.

III.6 Visualisation techniques

- **Memory hooks**

MEMORY HOOKS is a technique which involves stimulating imagination and enhances better memorization of numbers, size, relations and constructing association systems. It uses a natural ability to create in the mind images of different states of affairs. The teacher introduces students into the situation, asks them to imagine certain things and stimulates their imagination by means of asking questions. (Imagine the journey to the Land of Inventors. What can you see? Describe your experience). Students can also work with work cards, prepared by the teacher.

III.6.1 Practical methods

- **Film-based activities**
- **Project work**
- **Guided instruction method**

FILM-BASED ACTIVITIES – Students watch a film. Either they are given tasks to perform during the presentation or they are asked to focus only on watching a film.

Having watched the film, they receive worksheets to work individually or in groups.

Variants:

- **Creating the end of a film**

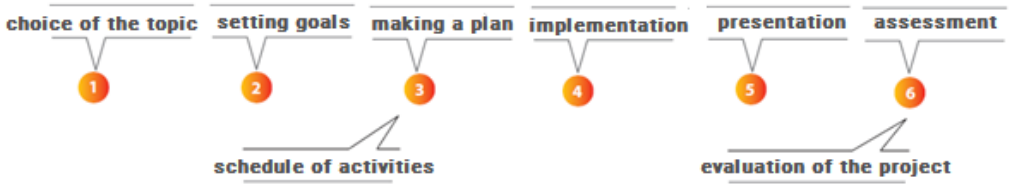
Students are shown the film, when it reaches the climax, the teacher stops it and the students speculate about the end of the film. They present their ideas in groups, choose the best ending and work on it. Then they compare a fictional film ending with the real one.

PROJECT WORK is a strategy which lets students learn, observe, measure and predict changes in a natural world and human activity. It allows for gathering information and drawing conclusions, as well as puts into practice mathematical and natural sciences knowledge. Students work more intensively and independently, which fosters a long-term retention of knowledge and skills. The project is an active method; it is a cognitive and practical activity at the same time. Thanks to pre-planned activities, the full mobilization of students takes place. They solve real problems, existing in the surrounding environment.

Project work has the following stages:

1. **Choosing the topic**.
2. **Preliminary preparation** i.e. formulating instructions, distributing tasks, setting up a project contract with students and establishing deadlines for consultations.
3. **Implementation**, which involves collecting and organizing information, tasks implementation and writing a report.

4. **Presentation**, which requires following instructions and all the members of the group participate in it.
5. **Evaluation,** which combines group work assessment, personal evaluation as well as the evaluation of the implementation of project stages and the end-products in accordance with the instruction criteria. Students' self-assessment should be part of evaluation.



Stages of the project

GUIDED INSTRUCTION METHOD is a variation of a project work. Students perform tasks that are premeditated and prearranged by an educator. It is a form of problem-solving teaching. Learners receive a practical task. They have access to all the data. They are also provided with information concerning the solution of analogous problems. Students work independently referring to so called „guiding texts" i.e. "guiding questions". Instead of using instructions, including all the information necessary for fulfilling a task, learners plan their work independently using source materials. Questions prepared by the teacher beforehand help students find solutions.

III.7 Strategies for developing mental skills and planning own work

- **What are my learning modalities**
- **Semantic differential scale profile**

WHAT ARE MY LEARNING MODALITIES? This strategy allows for identifying class prevalent learning styles. Students are given questionnaires and are asked to fill in the gaps, in accordance with their first impressions, with the phrases provided by the teacher: "I can see", "I can hear" or "I can feel". Having summed individual students' scores, it is required to prepare a class summary and let students draw conclusions. It is advisable to raise students' awareness of their learning styles, give them some prompts and suggest writing them down in their notebooks.

SEMANTIC DIFFERENTIAL SCALE PROFILE – the teacher prepares a scale profile with antonymous phrases depicting learning process, placed on the opposite ends of the scale. Each learner determines the value which in their opinion reflects their assessment of learning. Having the points connected, each learner can see their individual learning styles. Then the results are transferred into a collective poster. The comparison of profiles should lead to making a decision concerning the improvement of the class learning profile.

III.8 Evaluation methods

- **Questionnaire**
- **Mood Barometer**

- **Graffiti Board**
- **Feedback**
- **Class atmosphere**
- **Basket and briefcase**
- **Sky map**
- **Cooperation assessment**
- **Dartboard evaluation**

QUESTIONNAIRE is a research instrument, adapted for the purpose of gathering opinions, which guarantees students' anonymity.

MOOD BAROMETER is one of evaluation techniques used for assessing the mood of the group, and can be applied at the end of the lesson or at any stage of the lesson. On the poster with pictograms individual students dot their mood and at the end of this activity a final discussion takes place.

Variations:

- **Smiley Chart**

A poster with a lesson assessment diagram is prepared (specific criteria are provided). Students choose and dot with a felt-tip pen a place (one for each criterion), which is a response to a question asked by the teacher, e.g. "Was the subject of today's lesson attractive? Was the new content presented in an understandable way? Was the atmosphere in class good?" At the end of the lesson the results are discussed. In this way you can evaluate the last three lessons by asking the question: "Which of the last three lessons was in your opinion the most interesting one?"

GRAFFITI BOARD –students (individually or in groups) complete written by the teacher sentences and displayed on the classroom posters, e.g. "I have liked…/I haven't liked…"/ "I hope that by the end of the lesson ..." / "Personally, I can contribute to lessons in such a way that ..." or "…is what I like about this hero."/ "…is what I don't like about this hero."/ If I were him, I would…".Posters should be used for discussion or conversation.

FEEDBACK – it is an attitude or a matter of culture rather than a strategy; each person's statement evokes the reaction of the person – a message recipient. In turn these reactions affect the behaviour of the first speaker and other members of the group. Feedback may be positive or negative. It is also a form of communication, not always a verbal one. Gestures, body language, voice or even silence can be a form of expression.

Variations:

- **Information backpack**

Some students have a document sleeve attached to their backs. The other students write down on the slips of paper answers to questions (e.g. "Have you enjoyed working with me? Why?", "What did you like about me most?", "What didn't you like about me?", "How would you like to work with me?") and put them into "the backpacks" of the people,

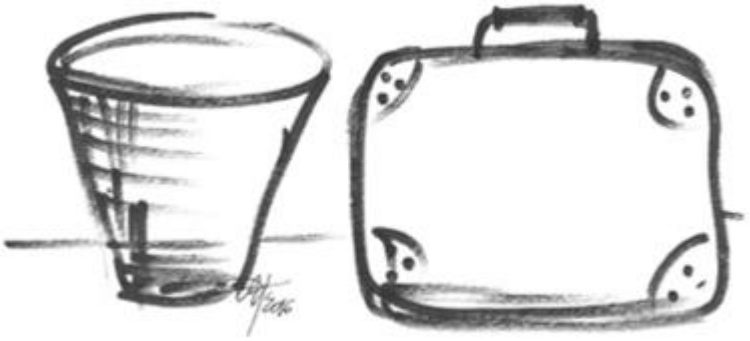
who are expected to answer their questions. Each person goes through the answers and provides a brief feedback on them.

- **Packing suitcases**

Students receive cards, which symbolize a suitcase, and write down their names on them. One by one the students come out of the room. In the meantime, other students prepare feedback and write it on suitcases. Having returned, the "owners" of the suitcases read silently the feedback given by the class and may respond briefly to that information.

CLASS ATMOSPHERE – this method is used for providing feedback on the atmosphere in the classroom and fosters introducing changes. Students fill in a questionnaire prepared by the teacher and prepare a summary report in groups. Then they form a group of experts to prepare a collaborative summary concerning a particular issue. The results of the work are recorded on the poster. Each group presents its poster by formulating a proposal, which results from the previous analysis. Conclusions are written on the board. Everyone looks for solutions that will improve learning atmosphere.

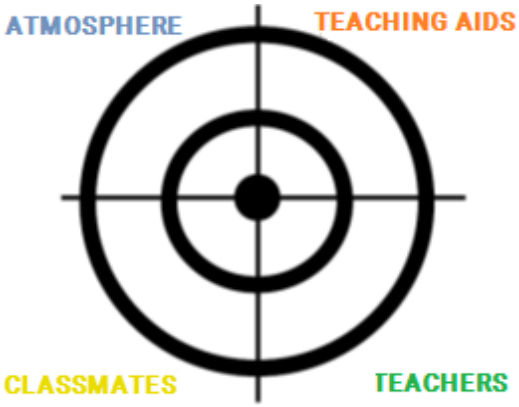
BASKET AND BRIEFCASE – this method is part of a SWOT analysis (S - strengths W - weaknesses O – opportunities/ chances T - threats). The teacher prepares two posters, one with a basket and one with a suitcase. Students receive cards in two colours. On one of them they write e.g. positive character traits of a literary hero and on the other the negative ones. They stick the cards onto the posters: the ones with positive characteristics are placed on the poster with a suitcase and the ones with negative characteristics on the poster with a basket. One of the students reads out information from notes, and then all the students express their opinions and discuss the results of the work.



SKY MAP – the teacher prepares the picture of a sky map and informs students that the map symbolizes their class or group. Students' task is to mark on the scheme their place in the classroom or in a group, and possibly also the place of other group members or a particular classmate. Students can also highlight places where they would feel best. The results should be discussed. All the students should explain why they have chosen a given position and who is the nearest to them, who is the farthest and for what reasons.

COOPERATION ASSESSMENT – students fill in a questionnaire, which can be used to assess class work. The appointed group prepares a questionnaire at home and presents the results at the beginning of the next lesson.

DARTBOARD EVALUATION – the teacher draws a dartboard on the board or a poster, taking into account some aspects of the lesson that are to be assessed by students, e.g. class atmosphere, teachers, classmates or teaching aids. Each student is given four darts (small self-adhesive notes, so-called price labels) and is asked to stick them on the dartboard. The teacher may leave a classroom for a while. Results can be discussed with the class, but it is not necessary, unless students want to comment on them.



III.9 Group work

If for the purpose of the lesson it is necessary to analyse or solve specific problems, the best results are achieved by working in small groups. Working in small groups involves collective, set by the teacher, task or exercise performance. It activates all students, because they have to cooperate while analysing a task, discussing, determining the methods of solving a problem, organizing knowledge in a creative way, before the final results are presented. Working in small teams has many advantages, but in order to be effective, it must be well planned and organized.

Summary

A paradigm shift in mathematical and nature sciences education, student-centre teaching and the growing popularity of constructivism as a starting point of planning a teaching process has aroused an interest in modern methods of teaching and experience-based learning.

A modern approach to teaching methods, from the perspective of both a teacher and a student, relies on the following assumptions:

- The teacher and the student are partners – both sides are equally responsible for the results of joint work. They decide together on the ways of obtaining results.
    - The teacher and the student take on new roles. No longer is the teacher an omniscient authority, but he becomes an advisor and an organizer. Students from a passive recipients turn into active participants, responsible for planning, organizing and evaluating their own work. The reversal of roles is possible provided both sides are required to articulate their needs including methodological support.
    - The aim of school is to prepare the student for independent work; students need to be told how to organize their own workshop, how to rationally plan the time of learning, and in general how to learn (at home, while doing projects, during individual work in the classroom).
    - Mobilising the internal potential of the teacher and the student does not need ready-made solutions, but examples and impulses as well as incentives to experiment and to gain knowledge in different ways.

Searching for ideal solutions fosters the effectiveness of teaching and learning Mathematics and Natural Sciences.

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