INDISPENSABLE ROLE OF MODERN METHODS OF TEACHING – LEARNING MATHEMATICS AND RELATED SUBJECTS: A PANACEA FOR ACCESS TO QUALITY EDUCATION

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Abstract

The aim of this paper 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, it shows how teachers apply active methods, assess the effectiveness of their work and how students respond to this way of teaching. Teaching of Mathematics is not only concerned with the computational know-how of the subject but is also concerned with the selection of the mathematical content and communication leading to its understanding and application. So, while teaching mathematics, one should use the teaching methods that are much more fruitful in gaining adequate responses from the students than we have ever had in the past.

Teaching Mathematics and Natural Science 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 facilities logical thinking and expressing ideas, planning and organizing the learning process, collaboration and responsibility; it prepares for life in a modern world and enables an individual to perform his/her work effectively. 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.

Modern Methods of Teaching-Learning Mathematics and other Related Subjects

On account of social changes towards knowledge driven society and new educational needs relating to strategies, methods and techniques for teaching Mathematics and Natural Sciences, new pedagogical trends appears, promoting "learning by doing, experiencing and communicating", (Malgorzata, Adam, Genowefa, 2017).

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 wells 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, requiring 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.

According to Joshi (2008), 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 analyzing real situations. Furthermore, 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 carryout 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 above mentioned 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 their 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 plays 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 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, 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 above mentioned 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.

Conclusion

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.

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

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