

# Effective Methods for Teaching Mathematics and Informatics in Higher Education in the Digital World

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**Abstract** – In the present paper we would like to share our technology enhanced, interactive and student centric approach applied during our long-lived experience in teaching mathematics and informatics in higher education institutions. Our goal is to develop active-engagement student-centered environment instead of the traditional instructor-centered environment. Our teaching is based on cooperative learning, flipped learning, guided discovery, laboratory approach, simulations and investigations. It is oriented to the application of modern technologies and involves research elements.

**Keywords** – student-centered environment, flipped learning, guided discovery, simulations, research based teaching, interdisciplinary approach.

## 1. Introduction

The training of students nowadays, in the conditions of the large volume of information from numerous digital sources, is a great challenge for teachers.

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The emphasis of the training is shifted from the accumulation and memorization of knowledge to the analysis and extraction of useful information needed to solve specific practical tasks.

Teaching mathematics is a very challenging process because of the abstract nature of theoretical formulations. Many students find abstract thinking difficult. Therefore, teaching methods must provoke the interest of students in order to overcome their feeling of anxiety. Mathematics helps humanity to understand the world but many students have difficulty realizing the relation of mathematical statements to real life. Providing application examples and including research experience motivates the students.

Besides, it is important to understand that learning is not only acquisition of knowledge and skills but also a social process [1]. Most of the methods require teachers not only to organize the material and educational goals for the learning process, but also to model and moderate the interactions between students and between students and teachers. These extra efforts are worth it because the interactions have a positive influence on the learning outcomes as discussed in [2].

## 2. Pros and Cons of the Main Training Methods Applied in our Practice

The most traditional method is exposition – the teacher explains the main concepts, gives examples and provokes a dialog with the students. This method is widely used. It requires less preparation, especially for teachers with long experience. But it is not a student centric approach and the students find it boring because of their passive role.

Present students like to be involved more actively in the learning process. One of the challenges involves games. Learning by playing games activates their attention and motivates them for better

understanding and retention. Games are effective tools for simulation of real world problems. There are many web resources such as Kahoot, Quizlet, Socrative, etc. which can be used for organizing games. But compiling materials for organizing games is a time consuming process and sometimes it is difficult to control the students and prevent the noise. Unfortunately, this approach is not suitable to all topics of the syllabus and it should be applied precisely and with measure.

Playing games combines well with the method of co-operative learning – students work in groups, discussing the solutions to the problems. This method encourages the team work and social interaction. The role of the teacher is changing from leader to facilitator and initiator. This method develops a sense of responsibility to other members of the group and contributes to the concentration and realization of the full potential of students. It is successfully applied for the tutorials. The main disadvantage of the method is the difficult management of all groups simultaneously.

From our experience, many students prefer group learning because of the opportunity to participate more actively in the learning process, to express their opinions without worries and to compare their assimilation of the material with the other participants in the group. The competition between the groups motivates the students to develop their full potential and to feel satisfied with their efforts.

During the online education, working in groups is facilitated by the set of mobile applications, as Viber, WhatsApp, Kahoot, etc., that can be used for tutorials, homework or course projects.

One of the most provocative teaching methods is guided discovery. It is opposite to the exposition method and matches the category of synthesis of the Bloom’s taxonomy [3]. The learners are not given the rule or generalization. On the base of series of examples or particular situations, the students have to discover the generalized rule. For example, teaching derivatives or integrals of polynomials, the teacher can show the derivatives or integrals of some polynomials and the students discover the rule themselves. Self-discovery of the generalized rule leads to its more permanent memorization and application. Sometimes the students find difficulties which can lead to frustration. In such case, the teacher has to assist and guide them, directing them to the right answer.

One form of discovery is investigation. Applying this method, the students define the problems, set the procedures and try to solve them. Investigation is time consuming and it is very good for home works, course works or group projects. Sometimes, more than one solution are correct. This provides an opportunity to develop students' creative abilities and leads to improving their adaptive capabilities. Such

an approach requires a high degree of teachers’ efforts but makes the teaching process very effective and applicable to the real life. This method highly motivates the students and leads to their satisfaction. They develop their own spirit of inquiry. Investigation is oriented to the highest level of the Bloom’s taxonomy pyramid - “Create – produce new or original work”. It can be combined with the method of co-operative learning.

The Laboratory approach or “learning by doing” is used to build readiness for the development of more abstract concepts. For example, teaching theoretical concepts of mathematics, combined with laboratory experience of numerical methods and programming or physical experiments illustrates the material taught and makes it more accessible to students. In the field of informatics, the approach of “learning by doing” is very well accepted by the students, but there is a certain risk of applying ready-made templates in solving specific tasks without fully understanding the concepts behind the solution applied.

The method of simulations provides a reconstruction of a situation or series of events that may happen. A simulation requires each student to make decisions based on previous training and available information. It is a student-centered approach to learning. Very often this method is combined with the co-operative learning and relates mathematics to “real life situations”. Unfortunately, like playing games, this method is not applicable to all topics of the subject. It is time consuming for the teacher and may provoke more than permissible emotions and noise among the students but the advantages are more than the limitations.

We can summarize the application of the presented methods from the revised Bloom’s taxonomy point of view in Table 1.

Table 1. Teaching methods/ Bloom’s taxonomy

Teaching method	Bloom’s Taxonomy level
Exposition	Remembering Understanding
Playing games	Understanding Applying
Co-operative learning	Understanding Applying
Guided discovery	Analysing Synthesis
Investigation	Analysing Evaluating Creating
Laboratory approach	Analysing Evaluating Creating
Simulations	Analysing Evaluating Creating

### 3. Some Innovative Approaches to the Teaching-learning Process

#### 3.1. *Linking Research into Teaching*

The knowledge of mathematics and informatics is useful and motivates students when it can be applied to particular situations in practice. Linking research into teaching enhances the following important graduate attributes: critical understanding, awareness of the provisional nature of knowledge; ability to identify the problems/issues and evaluate and apply evidence based solutions. Students highly appreciate home works and course projects which involve research elements. They feel themselves as co-creators of knowledge and build their own worldview through experience.

The research experience of the lecturer plays a key role in the successful implementation of this approach. Our long research experience in the fields of mathematics and informatics is a prerequisite for generating ideas in this direction.

For master, PhD students and young researchers, real tasks are very useful because they usually need methods on different levels, e.g., conceptual, mathematical, informatical, numerical, and computer modelling, data analyses and visualization. Sometimes the method for choosing a suitable conceptual method is an important part of the education by investigation and may lead to research papers [4].

Integrating research and teaching prepares the students to develop strategies, techniques and tools needed to solve complex and difficult real-life problems [5], [6]. Students feel themselves engaged in the process of discovering new knowledge and solutions and this motivates them to perceive learning as an interesting, challenging and useful activity.

This approach encourages students not only to solve the existing problems but also to create ideas and other problems which need solutions. The role of the teacher in this process is to guide, provoke, encourage, and distinguish the right from the wrong solution.

Integrating research and teaching is a step to convert the universities to the knowledge-building communities where academics and students work in partnership to generate and disseminate knowledge. In these communities, communication is built on the basis of dialogue and discussion, conducted and led by the teachers.

#### 3.2. *Flipped Learning*

To achieve the long-term goal of creating knowledge-building communities, it is necessary to

start with the active participation of students in the learning process. They should be given small tasks which they can perform easily and willingly. The independent participation of students in the learning process can be carried out by the method of flipped learning - a student-centric pedagogy in which lecture is moved to the online environment and class time is spent engaging in active learning experiences [7]. We provide students with materials - articles, lectures, video tutorials, etc. on which they prepare to understand the new topic of the syllabus and during the class meeting the topic is discussed and specific tasks are solved. In this way, the students are more actively engaged in the learning process and they take their learning responsibilities more seriously.

Flipped learning has many advantages: it creates dynamic and interactive learning environment, develops students' creativity and engagement, gives them more control over their education. But there are also disadvantages: self-preparation takes more time for students and creates difficulties for slow learners. Also, it is possible to miss understanding some important topics of the educational content. The preparation of the learning materials is a time consuming and difficult task. The teacher must carefully choose the material and present it in a clear and understandable form. Its volume should not be too large to avoid overwhelming students.

One of the main problems of teaching mathematics or informatics is the need to remind students of definitions, concepts, rules and syntaxes they have studied before. For this reason, it is necessary to add reference materials containing such information.

At a more advanced stage, when students have understood the usefulness and effectiveness of this approach, they are given more challenging tasks, such as finding and preparing the necessary materials for the topic. In this case, the teacher and the students change their roles initially. Individually or in groups, they can prepare a presentation of the lesson. The teacher and the other students ask questions and provoke discussions. The role of the teacher is to focus the students' attention at the most important points and to explain in details the most difficult topics in such a way that they can be understood even by slow learners.

From our experience, some students like to prepare themselves videos where they explain the lesson. As the students are familiar with the advanced technologies they accept and perform such tasks with pleasure. The learning process is optimized when students take a leading role.

#### 3.3. *Blended Learning*

Blended learning is a pedagogical or educational approach that combines traditional teaching methods,

such as in a classroom setting, with e-learning technology, such as online courses, lectures, presentations, quizzes, games, etc. [8]. It is a hybrid method which integrates technology and digital media with traditional lecturer-led classroom teaching.

Blended learning has many advantages as: flexibility and personalization in creating course modules, interactive simulations, students' engagement, independence of geographical constraints, etc. But it requires high skills in e-learning of teachers and students and significant investment in technology resources.

From our experience, some students prefer to learn by reading, others prefer learning by doing. Blending learning provides different approaches: co-operative learning, playing games, online quizzes, etc. Unfortunately, there is a lack of access to educational technologies for many students but the increasing of open educational resources leads to significant cost reduction.

Over the last decade, there have been at least five meta-analyses that have addressed the impact of blended learning environments and its relationship to learning effectiveness. These studies have found small to moderate positive effect sizes in favor of blended learning when compared to fully online or traditional face-to-face environments [9].

Both, flipped learning and blended learning provide an effective way to present the course materials, engaging students, which is very effective in critical cases as pandemic situations, natural disasters, etc.

#### **4. Application of Technology to the Teaching Process**

Technology is a key factor for the effective teaching and learning process. The dynamic development of modern knowledge places the emphasis in the training on the development of abilities for adaptation and continuous acquisition of new knowledge and skills. In the presence of a huge amount of information from many sources, it is essential that students have the ability to find the most appropriate information to solve a specific practical problem. The role of the teacher in this process is changing from provider to facilitator.

There are at least five hierarchical levels at which technologies may be used: presentation, demonstration, drill and practice, interaction, and collaboration. The potential for interactive and collaborative learning can be best achieved by networked computers and connectivity to the World Wide Web [10]. Online educational frameworks can be used even for performing exams and quizzes [11].

The main goal of education nowadays is to create habits and skills in students to self-study throughout their lives. Familiarity with advanced technology creates prerequisites for lifelong learning. Also, online education is a good alternative in emerging situations [12].

The application of a variety of ICT tools enhances the students' learning experience as well as their IT skills [13]. It has a positive influence even on teachers. The modern textbooks should be digital books, containing many references to other electronic resources.

Teaching mathematics needs to use MATLAB, MAPLE, Scilab or other products, designed to connect the theoretical mathematical concepts with the solutions of specific applied problems. For example, evaluating integrals or solving differential equations is easier using such packages.

Using Concept Maps [14] we present the information visually – by charts, graphic organizers, tables, flowcharts, Venn Diagrams, etc. Concept Maps help also to analyze and compare the information. For example, the similarity and differences between two ideas can be visualized by two intersected circles. To create visual concept maps we are using applications like Mindomo, TheBrain and Miro.

Kialo Edu [15] is a very good tool for discussions and teaching critical thinking. This is a collaborative platform, encouraging students to work together and exchange their ideas and opinion. In this way, they can demonstrate their knowledge and develop critical reasoning skills.

Go Animate is a software, available online, which provides the opportunity to include animated objects in the lesson presentation. Animation breaks the monotony and boosts students' enthusiasm to learn. In mathematics and informatics regular revision is essential for deeper understanding but repeating the main rules using the same methodology is monotonous and ineffective. The important learning outcomes of any topic of the syllabus can be recreated in an animation format at the end of the lesson. Animated characters increase students' interest. They can present a dialog between a teacher and students. It is more effective when the students' voices are involved in the record. Learners enjoy interactive learning through cartoon teaching since it is efficient, effective and flexible. It facilitates the comprehension of abstract concepts and assures a more meaningful and permanent learning [16].

Today's students in higher education belong to the so-called Generation Z who was born into integrated and globally connected world through the Internet. This generation uses social media and mobile devices before going to school. They are kinaesthetic, experiential, hands-on learners who prefer to learn by

doing rather than being told what to do or by reading text. Such learners prefer to solve problems and find solutions themselves. Their gaming experience leads to challenge-based learning. Their creativity and collaboration make them more reflective and independent learners than other generations [17].

Teaching and learning nowadays is based on cloud computing, mobile technology and virtual reality. There are many cloud-based tools which facilitate teaching process – Open Educational Resources (OER), Massive Open Online Courses (MOOC), Google Apps, You Tube, Drop box, etc. [18]. Massive Open Online Courses are free of charge and became widely used academic platforms. The enrolled participant can exchange their opinions and ideas in the existing forums, developing creative and critical thinking.

Virtual reality uses tools as VR goggles which provide an artificial environment using sounds, 3D images, creating an impression of immersing in a non-physical world. There is an opinion that virtual reality will replace the traditional classroom learning environment [19].

Another important technology used in education nowadays is augmented reality. It allows an addition of digital content to printed materials or objects. The students can scan an object using for example tablet and they will see the digital content. The digital content can be a link to a website, a video, a 3D model or other digital information [20].

Teachers nowadays have to consider the student's interest in the digital world and must connect the process of education to this world. Students appreciate mobile technologies because of their flexibility of time and locations. The mobile technologies provide downloading, uploading and online working via wireless or mobile networks. The main platforms for such connectivity include smart phones, PDAs, MP3/MP4 players, tablets, mini notebooks, gaming devices, etc. [21]. They are accessible and easy to use by students.

## 5. Conclusion

In this paper, we have presented some theoretical concepts and empirical findings about methods of teaching mathematics in higher education, which we consider as most effective, on the base of our long experience. We focused at students-centered methods, based on the latest technologies. The main goal of teaching nowadays is to provoke the analytical, critical and creative thinking and develop skills of life-long studying. Our students have to be prepared to meet the challenges of the rapid development of technologies in the digital world. To achieve this goal, it is necessary to apply a combination of the presented methods. The teachers'

responsibility is to choose the proper combination of methods which is most suitable for their students. This is a very challenging task that has to be performed with the active participation and the feedback of the students.

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