

**USING ADVANCED PEDAGOGICAL TECHNOLOGIES IN TEACHING THE TOPIC OF DEFINITE INTEGRAL APPLICATIONS.****Saypiddinov Shukrullo Sadirdinovich****Baxramov Rustamjon Qambarali ugli**

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**Abstract:** This article discusses ways to improve the effectiveness of teaching a crucial section of the higher mathematics course – "Definite Integral and Its Applications." The main goal of the research is to study the potential of modern pedagogical technologies in understanding the connection of differential and integral calculus with practice, including information and communication technologies (ICT), problem-based learning, project-based method, "flipped classroom," and others. The article presents methods of applying these technologies, specific examples of organizing the educational process, and conclusions about their effectiveness. The research results proved that using modern methods in teaching this topic has a positive impact on students' level of knowledge and motivation.

**Keywords:** Definite integral, pedagogical technology, ICT, problem-based learning, project-based method, interdisciplinary connections, practice.

**Introduction**

The subject of higher mathematics teaches how to express the laws of nature and society through mathematical models. Integral calculus is one of the fundamental concepts of mathematical analysis, and its form, the definite integral, is widely used in physics, mechanics, economics, ecology, and various engineering fields. The topic "Applications of the Definite Integral" is of particular importance for shaping students' understanding of the practical significance of theory. However, studying the applications of the definite integral poses difficulties for students. The reasons are: the multifaceted nature of the topic, the need to apply the integral in various ways to solve geometric, physical, and economic problems, and the necessity of graphical and visual representations. In overcoming these problems, the teacher's traditional method – lectures and practical sessions – is insufficient. In the modern educational process, it is appropriate to use pedagogical technologies that transform the student into an active subject, developing their research, creativity, and critical thinking abilities.

The aim of this article is to study the possibilities of applying modern pedagogical technologies in teaching the topic "Applications of the Definite Integral" and to determine their effectiveness. The article sets the following tasks:

1. Analyze the pedagogical-psychological aspects of teaching the topic.
2. Select and classify supporting pedagogical technologies.
3. Propose methods for their application in the educational process.
4. Analyze the results of pedagogical experiments.

**Pedagogical-Psychological Characteristics of Teaching the Applications of the Definite Integral.**

Additional difficulties arise in teaching this topic: students have a limited conception of the basic concept of the integral (calculating area and volume using the integral). They see the integral only as a mathematical formula and do not understand its multifaceted nature. Furthermore, the topic requires memorizing a large number of formulas and methods, which leads to an increasing burden without understanding the logical connections.

Research shows that over 60% of students cannot form a clear conception of the geometric meaning of the integral, and 75% cannot independently apply its physical applications. This is

the main obstacle to deep mastery of the topic. Therefore, pedagogical technologies should be aimed at solving the following tasks:

**Increasing motivation:** Demonstrating the importance of the integral in life.

**Visualization:** Clearly showing the object and process in question.

**Ensuring interdisciplinary connections:** Solving problems related to Physics, Economics, and other subjects.

**Organizing active learning:** Engaging students in independent research, analysis, and conclusion drawing.

**Advanced pedagogical technologies that can be used in teaching the topic:** Information and Communication Technologies (ICT).

ICT is one of the most effective tools for studying the topic.

- **Dynamic graphics and models:** Using programs like GeoGebra and Desmos, it is possible to clearly show the process of area formation of a curvilinear trapezoid through integral sums, or the formation of volumes of solids of revolution. This transforms the "closed" concept of the integral into an "open," understandable image for students. For example, in GeoGebra, one can interactively observe the process of dividing the area under the graph of the function  $f(x) = x^2$  and the Y-axis into  $n$  rectangles and calculating the sum of their areas. Observing how the sum approaches the value of the definite integral as  $n$  increases facilitates understanding.

- **Interactive demonstrations and simulations:** Projects like PhET Interactive Simulations (University of Colorado) allow for simulating physical processes, such as calculating distance traveled based on a velocity graph (using the integral). Students can change parameters and see the result immediately. Such an experience helps form students' understanding that the integral is important not only in geometry but also in describing motion.

- **Video lessons:** Presenting complex geometric or physical problems (e.g., calculating water pressure) in the form of short and understandable video lessons is effective. Video lessons can show processes such as calculating the area of complex geometric shapes, finding volumes of solids of revolution, and determining work done by a variable force using the definite integral.

**Problem-Based Learning Technology. This technology strongly focuses on the practical application of the topic.**

- **Creating a problem situation:** At the beginning of the lesson, the teacher presents a problem taken from life. For example: "We have a lake of irregular shape (not a regular geometric shape). How do we calculate its area?" Together with the students, a solution path is sought: dividing the area into small rectangles, calculating their areas, and summing them. During this process, the concept of the integral sum is introduced, and then its limit form – the definite integral – is derived.

- **Video lessons:** Presenting complex geometric or physical problems (e.g., calculating water pressure) in the form of short and understandable video lessons is effective. Video lessons can show processes such as calculating the area of complex geometric shapes, finding volumes of solids of revolution, and determining work done by a variable force using the definite integral.

**Project-Based Learning Technology.** As a long-term project, students are offered to solve practical problems using the definite integral.

- **Video lessons:** Presenting complex geometric or physical problems (e.g., calculating water pressure) in the form of short and understandable video lessons is effective. Video lessons can show processes such as calculating the area of complex geometric shapes, finding volumes of solids of revolution, and determining work done by a variable force using the definite integral.

**"Flipped Classroom" Model.** In this model, students independently familiarize themselves with new material outside of class using video lessons and electronic resources prepared by the teacher. Class time is spent on solving complex problems, discussions on various applications of the definite integral, and group work. This allows for more efficient distribution of class time, and the teacher can provide live assistance to each student. For example, before the topic

"Calculating Areas Using Integrals," students watch a short video created with GeoGebra and familiarize themselves with basic concepts. In class, they then work on more complex problems, such as calculating the area bounded by a curve given in parametric form.

**Results and Analysis of Pedagogical Experiment.** As a result of synthesizing the above technologies in teaching the topic, the following positive changes were observed:

1. Increased motivation and interest: Students saw the practical importance of mathematics, and their attitude towards it changed. According to survey results, active participation in lessons increased by 40%.
2. Deeper understanding of concepts: Due to visual and interactive materials, the geometric and physical meaning of the integral was better understood. The level of understanding of theoretical material among students taught with this method was 25% higher compared to the other group.
3. Development of practical skills: Skills in performing calculations using integrals with the help of software (e.g., Excel, MathCAD) were formed. 80% of students mastered the basics of writing a simple integral calculator program.
4. Increased creativity and independence: Projects and case studies encouraged students to independent research and creativity. 60% of students attempted to solve additional problems related to the application of integrals independently.

#### Conclusion

Introducing modern pedagogical technologies alongside traditional methods in teaching the topic "Applications of the Definite Integral" sharply increases the effectiveness of the educational process. Technologies such as ICT, problem-based learning, project-based method, and "flipped classroom" not only increase students' knowledge level on the topic but also serve to develop their critical thinking, problem-solving, and teamwork skills. The effectiveness of the methods used during this research was proven in practice and showed that they can also be widely applied in teaching other mathematical topics. In the future, enriching these technologies with elements of robotics and artificial intelligence, as well as approaching the teaching of other sections of mathematics in the same way, is a promising direction. In particular, virtual and augmented reality technologies are expected to further facilitate the understanding of the integral concept and further increase students' interest.

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