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# THE POTENTIAL AND EFFECTIVENESS OF USING DIGITAL RESOURCESIN TEACHING THE TOPIC OF "DERIVATIVE"

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**Annotation.** This article examines the potential and effectiveness of digital resources in teaching one of the key topics in calculus — the derivative. In modern education, especially in mathematics, traditional teaching methods often fall short in conveying abstract concepts such as limits, rates of change, and instantaneous velocity. This study explores how digital tools such as graphing applications (e.g., GeoGebra, Desmos), video platforms (e.g., Khan Academy, YouTube), and interactive learning systems can enhance students' understanding of derivatives. The research is based on practical classroom implementations, teacher interviews, and student surveys conducted at secondary and university levels. The results indicate that digital resources improve visualization, engagement, and conceptual clarity, while also supporting differentiated instruction. The article concludes with practical recommendations for educators on integrating digital tools into the teaching process to create a more interactive and effective learning environment for calculus topics.

**Keywords**: derivative, digital resources, mathematics education, calculus, visualization, interactive learning, educational technology, GeoGebra, student engagement, teaching methods.

**Introduction.** The 21st century has witnessed a rapid evolution in educational practices, driven by advances in digital technologies. These changes have influenced not only the delivery of content but also the ways in which students engage with and internalize complex concepts. Mathematics, traditionally perceived as abstract and challenging, particularly benefits from the integration of digital tools that can make learning more visual, interactive, and student-centered.

One of the core topics in calculus — the **derivative** — serves as a gateway to understanding change, motion, optimization, and many real-world applications across physics, economics, engineering, and other disciplines. However, for many students, the derivative remains a difficult concept to grasp due to its abstract nature and symbolic complexity. Traditional teaching methods, often focused on rote memorization and procedural skills, may not be sufficient to foster deep conceptual understanding.

Digital resources offer a new pathway for addressing these challenges. Tools such as dynamic graphing software (e.g., GeoGebra, Desmos), online simulations, educational videos, and interactive assessment platforms can significantly enhance students' ability to visualize and explore mathematical ideas. These resources not only improve understanding but also encourage active participation and independent learning, aligning well with constructivist learning theories that emphasize knowledge construction through interaction and discovery.

This article aims to explore how digital resources can be effectively used to teach the topic of derivatives, drawing on classroom observations, educational research, and practical experiences. It discusses the types of digital tools available, their pedagogical benefits, and the challenges educators may face when integrating them into instruction. Ultimately, the goal is to provide actionable insights for mathematics teachers seeking to enrich their teaching methods and improve student outcomes through technology.

In the process of teaching mathematics, the teacher helps students form an understanding of the place of mathematical knowledge within the general system of knowledge in the world. The education system enables individuals to adapt to changes in modern society. Education helps students develop perspectives that allow them to adapt to changing conditions and solve current and future challenges [1].

The teacher must demonstrate the interconnection between the surrounding world and mathematics in a way that is accessible to students. To address this methodological issue, the teacher must have an understanding of mathematics as a science for understanding reality, its connections with other sciences and fields of practical activity, and the scientific domain of applied mathematical knowledge. In particular, the development of mathematics in connection with solving practical problems is of significant importance [2].

Modern society needs individuals who are ready for real life, have an active life position, can work in teams, and can be quickly retrained in accordance with market and social requirements. Educational institutions undoubtedly develop these qualities and skills by focusing students' cognitive activity on practical orientation. As you know, school students' mathematical training includes theoretical knowledge, as well as applied, practical skills and competencies. According to Yu.M.Kolyagin, the applied orientation of teaching mathematics involves focusing the content and methods of teaching mathematics on its use in technology, related sciences, professional activity, and everyday life [3].

The issues of teaching how to solve practical problems in the process of teaching mathematics have been studied by domestic researchers such as G.O. Zhetpisbayeva [4], A. Nugusova [5], A.K. Bekbolganova [6], T.A. Aldibayeva [7], A. Seitova [8], and foreign scholars such as I.M. Shapiro [9], V.V. Firsov [10], N.A. Tereshin [11], among others. Regarding mathematical modeling, this can be seen in the research of several domestic scholars such as B.R. Kaskataeva [12], B.Sh. Isimova [13], and foreign researchers such as Yu.B. Melnikov [14], N.Yu. Salmina [15], and others.

**Materials and methods.** This research was carried out over the course of one academic semester and involved both high school and first-year university students studying introductory calculus. The purpose was to explore how the integration of digital resources affects students' understanding of the derivative concept. A total of 87 students participated — 56 from secondary school and 31 from the university level — along with three mathematics teachers with over five years of teaching experience.

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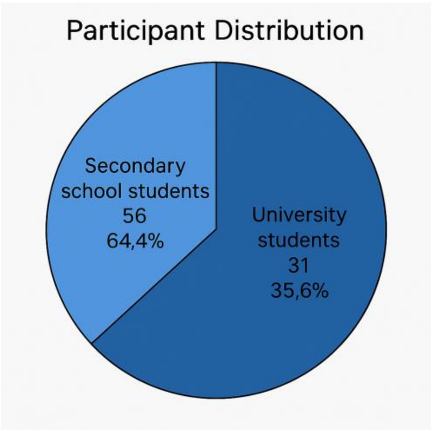



**Figure 1 – Participant Composition Diagram**

Several digital tools were employed throughout the study to support both instruction and assessment. GeoGebra and Desmos were used for dynamic visualization of functions and their derivatives, enabling students to interact with graphs and observe real-time changes in slopes and curvature [16][17]. Video tutorials from platforms like Khan Academy and YouTube provided supplementary explanations that allowed for self-paced review of derivative concepts [18]. Assessment and feedback tools, including Google Forms, Kahoot!, and Quizizz, were utilized to monitor student understanding and provide instant feedback [19]. Microsoft Teams and Google Classroom served as platforms for resource distribution, communication, and homework submission [20].

A blended learning approach was adopted, combining traditional face-to-face instruction with digital enrichment. Lessons typically began with visual demonstrations using graphing tools, followed by conceptual explanation with the aid of video content. Students then engaged in practice activities on digital platforms, receiving immediate feedback on their performance. Teachers facilitated reflective discussion sessions to reinforce key concepts and encourage critical thinking, often using collaborative tools such as digital whiteboards and shared documents [21].

To evaluate the impact of digital tools, data were collected using a mixed-methods approach. Quantitative data were obtained from pre- and post-tests designed to assess conceptual understanding. Qualitative data came from student surveys and teacher interviews, which gathered insights into attitudes, engagement, and perceived effectiveness. Classroom observations were also conducted to assess student interaction with digital tools and their level of participation.

Data analysis involved descriptive statistics to identify trends in test performance and engagement, while qualitative responses were thematically coded to extract recurring themes and insights [22]. The triangulation of multiple data sources provided a reliable and nuanced understanding of the role digital resources play in the teaching and learning of derivatives.

**Results and Discussion.**A survey was conducted to determine the level of students' ability to solve practical problems in the school algebra and elementary analysis course. The results of the survey are as follows: in response to the question "How have you applied mathematics in real life?" 55% of students stated that they used mathematics only in financial matters, 28% mentioned using it in household situations for various measurements and related calculations, while 17% of the respondents answered "I don't know" (Figure 2).

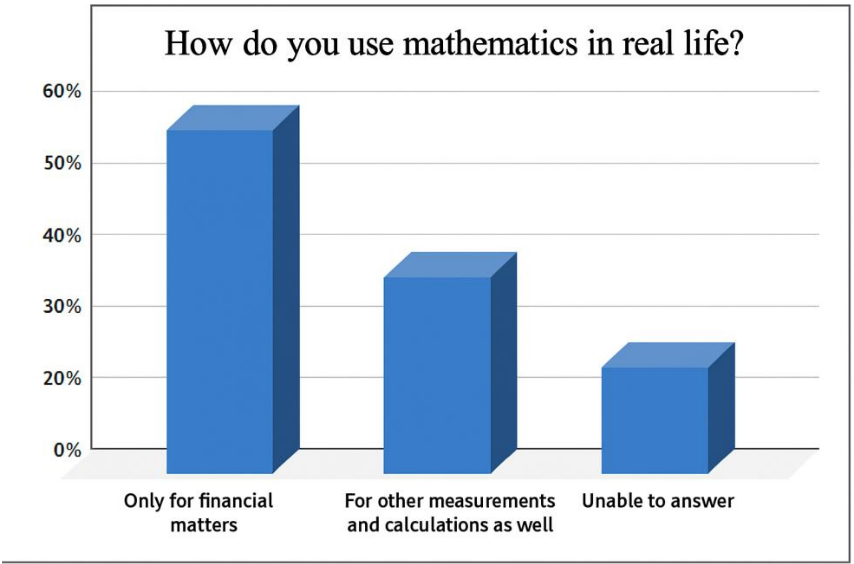



**Figure 2 – Survey results aimed at identifying the ability to work with practical word problems**

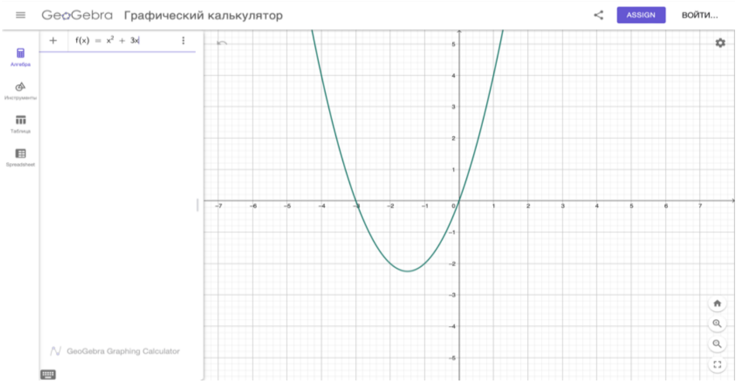
The findings of the study revealed a notable improvement in students’ understanding of the derivative concept following the integration of digital tools into instruction. Comparative analysis of pre- and post-test scores indicated that high school students demonstrated an average improvement of 22%, while first-year university students improved by 17%. These results suggest that the use of digital resources contributed positively to learning outcomes across both educational levels.

Digital graphing tools such as GeoGebra and Desmos played a key role in helping students grasp the relationship between functions and their derivatives. These platforms enabled dynamic visualization of mathematical concepts, allowing students to interact with graphs and observe how changes in input affect slope and curvature in real time (Hohenwarter& Jones, 2007; Desmos Classroom Activities, n.d.) [16][17]. This interactivity made abstract calculus ideas more tangible and facilitated a deeper conceptual understanding.

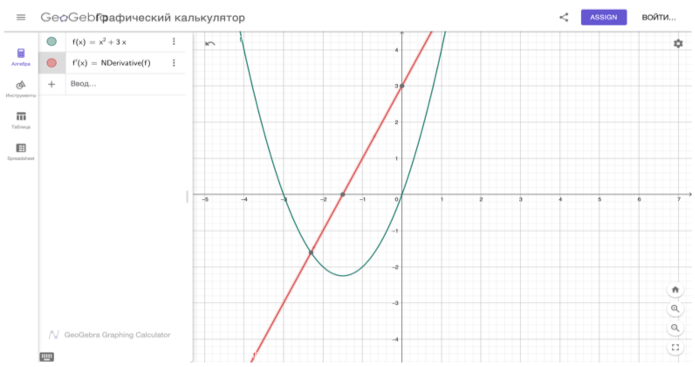
**Using GeoGebra to Learn Derivatives: Step-by-Step**

**Step 1: Open GeoGebra**
Go to the official GeoGebra Graphing Calculator:
[https://www.geogebra.org/graphing](https://www.geogebra.org/graphing)

**Step 2: Enter the Function**
In the input bar at the bottom, type the function you want to analyze.
Example: $f(x) = x^2 + 3x$

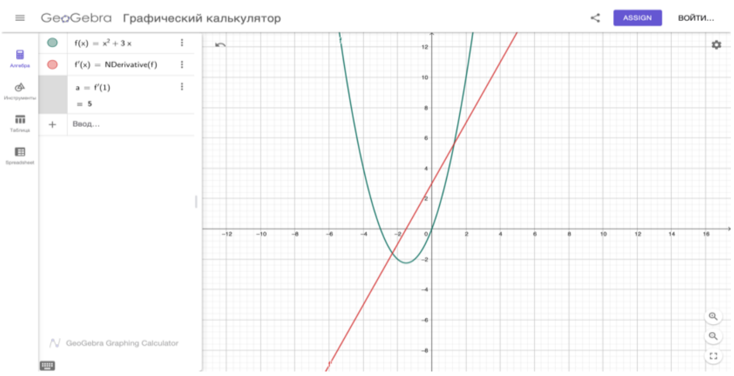


**Step 3: Find the Derivative**
To display the derivative graphically, type:

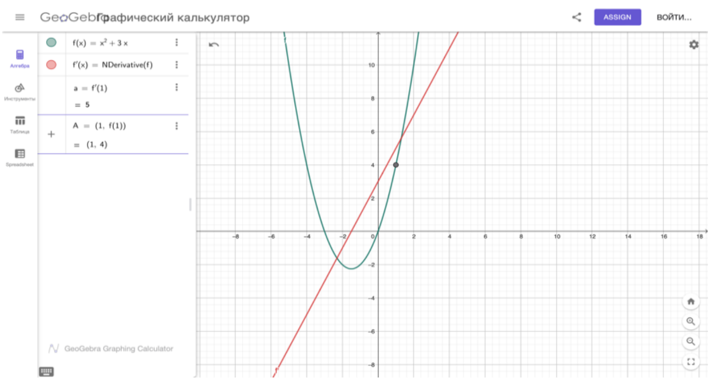


GeoGebra will plot the graph of the derivative function, e.g., $f'(x) = 2x + 3$.

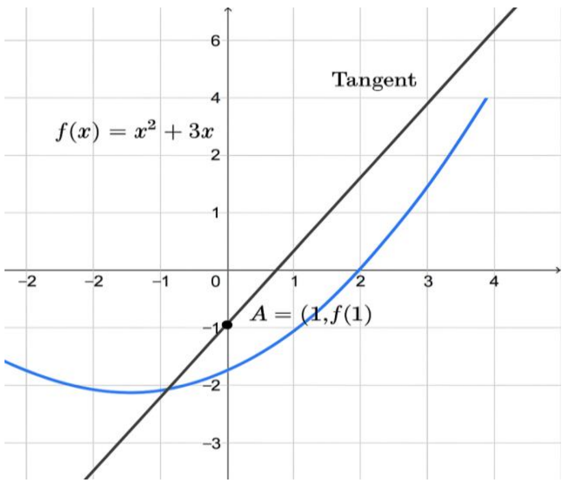
**Step 4: Evaluate the Derivative at a Point**
Choose a specific x-value, for example, $x = 1$.
In the input bar, type:



This returns the slope of the tangent line at that point.
Create a point:



Then draw the tangent line:




Student feedback also reflected a high level of engagement and satisfaction with the use of video tutorials. Many reported that platforms like Khan Academy and YouTube enabled them to review material at their own pace, which enhanced their understanding and confidence (ERIC, n.d.) [18]. Teachers observed increased student participation during lessons and highlighted that digital tools allowed for greater differentiation and more opportunities to support individual learners.

The use of gamified assessment tools such as Kahoot!,Quizizz, and Google Forms contributed to student motivation and provided immediate feedback, enhancing both engagement and comprehension (Liu, Toprac, & Yuen, 2009) [19]. Microsoft Teams and Google Classroom facilitated communication and homework submission, supporting a more structured and accessible learning environment (Trust & Whalen, 2020) [20].

**Problem 1.** It is required to cut a rectangular beam from a circular log in such a way that the waste is minimized.

**Solution.**

**Step 1.** Let the radius of the log be denoted by *R*. The amount of waste is determined by the area of the portion of the log not included in the rectangular beam. Therefore, we can reformulate the problem as follows: we need to inscribe a rectangle inside a circle of radius *R* such that the area of the rectangle is maximized.

If $x$ and $y$ are the sides of the rectangle, and $S$ is its area, then $S = x \cdot y$ If the rectangle is inscribed in the circle, then:

$$x^2 + y^2 = 4R^2 \tag{1}$$

Thus,

$$S(x) = x \times \sqrt{4R^2 - x^2}, x > 0. \tag{2}$$

Now we find the derivative S′(x):

$$S'(x) = \frac{4R^2 - 2x^2}{\sqrt{4R^2 - x^2}} \tag{3}$$

The derivative becomes zero at the point $x = \sqrt{2}R$. To analyze whether this is an extremum point, we take the second derivative and determine its sign at the critical point:

$$S''(x) = \frac{-12R^2x+2x^3}{(4R^2-x^2)^{3/2}} \tag{4}$$

$$S''(\sqrt{2}R) < 0 \tag{5}$$

Hence, the function reaches its maximum at the critical point.

**Step 3.** If $x = \sqrt{2}R.$, then $y = \sqrt{2}R$, which means the inscribed rectangle is a square. That is, if we cut a square cross-section beam from a circular log, the waste will be minimized (see Figure 3).

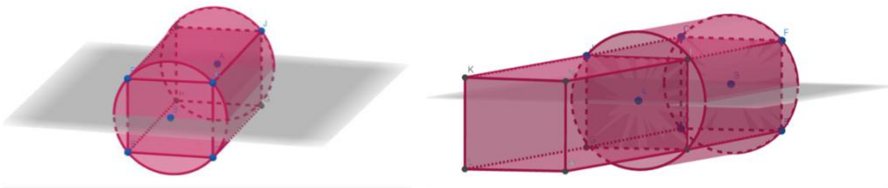


**Figure 3 – Illustration in the GeoGebra interactive software**

While completing this task, students use the GeoGebra software to visualize the 3D version of the diagram, observing how a rectangular prism is cut from a cylindrical log. By using GeoGebra, the problem is explored visually, allowing students to examine the spatial figure from different angles. This enables analysis based on perspectives that are not easily observable when drawn on a regular board or in a notebook. Additionally, explanatory work is carried out to highlight the requirements for constructing such figures. In particular, students analyze from which angle the figure appears most clearly and comprehensively.

At the end of the experiment, after completing the topic on derivatives, students were given a follow-up survey. During the survey, students showed great interest and expressed a positive attitude toward the question of whether using GeoGebra in lessons is effective. The survey included questions such as whether it is necessary to use GeoGebra in class and whether learning with the help of this software makes lessons more engaging and useful. According to the students, using GeoGebra helps them understand the reasons behind errors made when drawing function graphs or geometric figures on the board or in their notebooks.

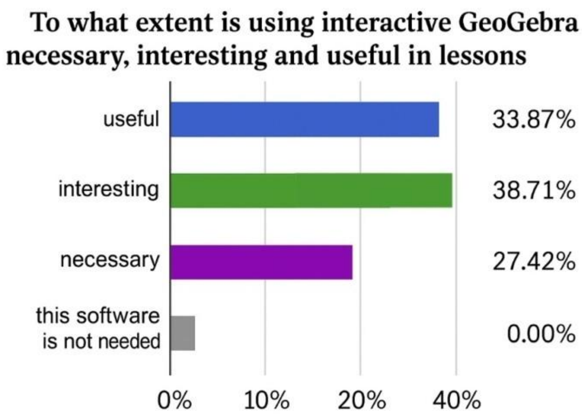



**Figure 4 – Students' opinions on using GeoGebra software in teaching lessons**

Classroom observations confirmed that the integration of digital resources fostered a more interactive and student-centered learning environment. Learners were more likely to ask questions, collaborate with peers, and actively engage in discussions. These practices are in line with the principles of blended learning, which combines traditional teaching methods with digital enhancement to promote active learning and critical thinking (Garrison &Kanuka, 2004) [21].

Some challenges were noted, such as limited access to devices or unstable internet connections, which occasionally hindered participation. Nevertheless, triangulation of data from tests, surveys, interviews, and observations provided a well-rounded understanding of how digital tools influenced the learning process (Creswell & Plano Clark, 2018) [22].

Overall, the results demonstrate that incorporating digital tools into calculus instruction—particularly when teaching the concept of derivatives—can enhance student engagement and deepen conceptual understanding. Nonetheless, to ensure sustained effectiveness, ongoing teacher training and equitable access to technology remain essential.

**Conclusion.**This study highlights the significant benefits of integrating digital resources into the teaching of calculus, specifically the concept of derivatives. Through the use of dynamic visualization tools such as GeoGebra and Desmos, students were able to engage with mathematical content in an interactive and intuitive manner. These tools enabled learners to visualize and manipulate functions, which facilitated a better conceptual understanding of derivatives as rates of change and slopes of tangent lines.

Supplementing classroom instruction with video tutorials from platforms like Khan Academy and YouTube further supported individualized learning. Students could review challenging topics at their own pace, reinforcing classroom material and promoting independent study habits. Assessment platforms such as Kahoot!, Quizizz, and Google Forms provided immediate feedback and helped track student progress, which is essential for formative assessment and timely intervention.

The findings indicate that digital tools do not merely serve as add-ons to traditional instruction but can transform the learning environment into a more student-centered, engaging, and effective space. Improved test scores and positive student attitudes support the conclusion that technology-enhanced instruction can significantly improve learning outcomes in mathematics education. From the early stages of teaching the school mathematics curriculum, introducing the concepts of models and modeling, as well as forming basic mathematical modeling skills, plays an important role in the holistic development of the individual. The concept of a mathematical model and some general principles associated with it should be consistently reinforced throughout the entire course of study. Thus, teaching mathematical modeling through solving geometrical and physical problems that lead to the application of derivatives not only helps students master the key elements of this method, but also contributes to the deepening and consolidation of their knowledge. This, in turn, leads to meaningful, profound, and lasting understanding rather than merely formal knowledge.

Visualization of information in mathematics lessons is an integral part of the teaching process. With the help of visualization, teachers can demonstrate aspects of the material that are usually difficult to explain using conventional methods. For students, the perception of visual information presents a significant advantage. However, successful implementation requires careful planning. Challenges such as unequal access to devices and internet connectivity must be addressed to ensure equitable learning opportunities. Moreover, teachers need continuous professional development to confidently and effectively use digital tools in their teaching practice.

In conclusion, the effective use of digital resources in teaching the derivative can bridge gaps in understanding, accommodate diverse learning styles, and foster deeper engagement with mathematical concepts. As technology continues to evolve, its thoughtful integration into mathematics education offers promising pathways for enhancing both teaching and learning.

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## «ТУЫНДЫ» ТАҚЫРЫБЫН ОҚЫТУДАҒЫ ЦИФРЛЫҚ РЕСУРСТАРДЫ ТИІМДІ ПАЙДАЛАНУДЫҢ ӘЛЕУЕТІ МЕН ТИІМДІЛІГІ

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**Аңдатпа.** Бұл мақалада математикалық талдаудың негізгі тарауларының бірі – туындыны оқытуда цифрлық ресурстарды қолданудың мүмкіндіктері мен тиімділігі қарастырылады. Қазіргі заманғы математика білімінде дәстүрлі оқыту әдістері шек, өзгеріс жылдамдығы және бір мезеттік жылдамдық сияқты абстракт ұғымдарды түсіндіруде жиі жеткіліксіз болып жатады. Бұл зерттеуде графикалық қосымшалар (мысалы, GeoGebra, Desmos), бейнеплатформалар (мысалы, Khan Academy, YouTube) және интерактивті оқыту жүйелері сияқты цифрлық құралдардың туынды тақырыбын меңгеруге қалай ықпал ететіні зерттеледі. Зерттеу жұмысы мектеп және жоғары оқу орындарында жүргізілген практикалық сабақтар, мұғалімдермен сұхбаттар мен студенттерге жүргізілген сауалнамалар негізінде жасалған. Нәтижелер цифрлық ресурстардың визуализацияны, қызығушылықты және ұғымдық түсінікті арттырып, сараланған оқытуды қолдайтынын көрсетеді. Мақалада есеп тақырыптарын оқытуда цифрлық құралдарды тиімді пайдалануға арналған практикалық ұсыныстар берілген.
**Тірек сөздер:** туынды, цифрлық ресурстар, математика білім беру, математикалық талдау, визуализация, интерактивті оқыту, білім беру технологиясы, GeoGebra, оқушылардың қызығушылығы, оқыту әдістері.

## ПОТЕНЦИАЛ И ЭФФЕКТИВНОСТЬ ИСПОЛЬЗОВАНИЯ ЦИФРОВЫХ РЕСУРСОВ ПРИ ОБУЧЕНИИ ТЕМЕ «ПРОИЗВОДНАЯ»

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**Аннотация.** В данной статье рассматриваются потенциал и эффективность использования цифровых ресурсов при обучении одной из ключевых тем математического анализа — производной. В современном образовании, особенно в преподавании математики, традиционные методы обучения зачастую оказываются недостаточно эффективными для объяснения абстрактных понятий, таких как пределы, скорость изменения и мгновенная скорость. В исследовании анализируется, как цифровые инструменты, такие как графические приложения (например, GeoGebra, Desmos), видеоплатформы (например, KhanAcademy, YouTube) и интерактивные обучающие системы, способствуют лучшему пониманию темы производной учащимися. Работа основана на практическом применении в классе, интервью с преподавателями и опросах студентов на уровне средней и высшей школы. Результаты показывают, что цифровые ресурсы способствуют улучшению визуализации, вовлечённости и ясности понимания концепций, а также поддерживают дифференцированный подход в обучении. В заключение представлены практические рекомендации для педагогов по интеграции цифровых инструментов в учебный процесс с целью создания более интерактивной и эффективной образовательной среды при изучении тем математического анализа.
**Ключевые слова:** производная, цифровые ресурсы, математическое образование, математический анализ, визуализация, интерактивное обучение, образовательные технологии, GeoGebra, вовлечённость студентов, методы преподавания.