



פרויקט מס' BS-CS-25-124

Platform/Model for Identifying Causes of Mathematical Errors

פרויקט הנדסי

דוח מסכם

הוכן לשם השלמת הדרישות לקבלת

תואר ראשון במדעי הטבע B. Sc.

מאת

לי וילנר 207870783

שחר לוי 315277418

בהנחיית ד"ר דביר רוס

הוגש למחלקה למדעי המחשב

המכללה האקדמית להנדסה סמי שמעון

באר-שבע

תאריך עברי

תאריך לועזי



כ' בטבת התשפ"ה
20/01/2025

פרויקט גמר

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חתימת סטודנט 1: _____ תאריך: _____

חתימת סטודנט 2: _____ תאריך: _____

חתימת המנחה: _____ תאריך: _____

אישור ועדת הפרויקטים: _____ תאריך: _____



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תקציר הפרויקט:

מתמטיקה - מה זה?

מתמטיקה היא תחום ידע רחב ומרתק העוסק בחקר כמות, מבנה, מרחב ושינויים. זוהי שפה אוניברסלית שבאמצעותה ניתן לייצג, להסביר ולפתור בעיות במגוון רחב של תחומים - מפיזיקה והנדסה ועד כלכלה ומדעי המחשב.

חשבון דיפרנציאלי ואינטגרלי הוא תחום מתמטי מרכזי ומאתגר העוסק בניתוח שינויים ותכונות של פונקציות. עם זאת, סטודנטים רבים נאבקים בהבנת הטעויות שלהם במהלך פתרון תרגילים, מה שמקשה על תהליך הלמידה שלהם. בעוד פלטפורמות קיימות מספקות פתרונות, הן לרוב אינן מעניקות משוב ברור ומיידי שמסביר את השגיאות.

כדי להתמודד עם האתגרים הללו, בפרויקט זה אנו מפתחים פלטפורמה אינטראקטיבית חדשה שמטרתה לסייע לסטודנטים להבין טעויות ולשפר את ביצועיהם בחשבון דיפרנציאלי ואינטגרלי.

הפתרון המוצע

הפרויקט כולל פיתוח אתר אינטראקטיבי המספק משוב מיידי וברור על תשובות הסטודנטים. האתר מתבסס על שאלות רב-ברירה ותומך במעקב אחר התקדמות אישית סטטיסטית של כל משתמש. על ידי שילוב של טכנולוגיות עכשוויות לפיתוח אתרים ושיטות הדרכה מתקדמות, הפלטפורמה מאפשרת למידה עצמאית ומעמיקה.

מטרות הפרויקט

- לעזור לסטודנטים לזהות ולהבין טעויות בצורה יעילה.
- להציע משוב מיידי ואישי שמשפר את תהליך הלמידה.
- להנגיש את הלמידה בתחומים מתמטיים מורכבים כמו חשבון דיפרנציאלי ואינטגרלי.

טכנולוגיות ושיטות

הפלטפורמה נבנית באמצעות HTML, CSS ו-JavaScript ומשלבת שאלות מתוך בנק תרגילים רחב. האתר עוקב אחר הביצועים של המשתמשים ומספק הצעות לשיפור בהתאם להישגיהם באופן סטטיסטי.

באמצעות הפלטפורמה, סטודנטים יוכלו להתמודד עם אתגרים בלמידת חשבון דיפרנציאלי ואינטגרלי בצורה נגישה, יעילה ומהנה יותר, ולהשתפר בצורה משמעותית.



Abstract:

Mathematics – What is it?

Mathematics is a broad and fascinating field of knowledge that explores quantities, structures, spaces, and changes. It is a universal language used to represent, explain, and solve problems in a wide range of fields, including physics, engineering, economics, and computer science.

Differential and integral calculus is a central and challenging branch of mathematics that focuses on analyzing changes and the properties of functions. However, many students struggle to understand their mistakes when solving problems, which hinders their learning process. While existing platforms provide solutions, they often fail to offer clear and immediate feedback that explains errors effectively.

To address these challenges, this project aims to develop a new interactive platform designed to help students understand their mistakes and improve their performance in differential and integral calculus.

Proposed Solution

The project involves developing an interactive website that provides immediate and clear feedback on students' answers. The platform is based on multiple-choice questions and supports personalized statistical progress tracking for each user. By integrating modern web development technologies and advanced teaching methods, the platform facilitates independent and in-depth learning.

Project Goals

- To help students identify and understand their mistakes effectively.
- To offer immediate and personalized feedback that enhances the learning process.
- To make complex mathematical topics like differential and integral calculus more accessible.

Technologies and Methods

The platform is built using HTML, CSS, and JavaScript and incorporates questions from an extensive exercise bank. The site tracks users' performance and provides improvement suggestions based on their statistical progress.

Through this platform, students will be able to tackle challenges in learning differential and integral calculus in a more accessible, efficient, and enjoyable manner, leading to significant improvement in their skills.

1. Introduction:

Calculus, encompassing differential and integral calculus, is a foundational component in the study of mathematics, particularly within engineering and science disciplines. It provides essential tools for modeling and understanding dynamic systems and changes. However, students often encounter significant challenges in mastering these concepts. Research indicates that many undergraduate students struggle with solving derivative and integral problems, often due to a lack of conceptual understanding and difficulties in applying appropriate problem-solving frameworks. [1]



To address these challenges, various interactive platforms have been developed to facilitate calculus learning. For instance, GraspLe offers ready-to-use courses on calculus, providing interactive exercises with direct feedback, enabling students to identify and correct mistakes in real-time. [2]

Similarly, Pearson's Interactive Calculus supports instructors and engages students through video-based instruction and interactive elements that offer immediate feedback.[3]

Despite the availability of these resources, there remains a need for platforms that not only provide solutions but also offer clear and immediate feedback to help students understand their errors effectively. This project aims to develop an interactive website that addresses this gap by supplying multiple-choice questions and personalized progress tracking, thereby enhancing the learning experience for students tackling differential and integral calculus.



2. Literature Review

2.1.1 Background

2.1.2 Understanding the methods and tools utilized in our project requires familiarity with several foundational concepts in mathematics education and interactive learning technologies. Below is a summary of the relevant background information.

2.1.3 Challenges in Learning Calculus

Calculus, encompassing both differential and integral calculus, is a cornerstone of higher mathematics, offering essential tools for analyzing rates of change and accumulated quantities. Despite its importance, many students face significant challenges in mastering calculus, including:

- **Difficulty Identifying Mistakes:** Many learners struggle to recognize and correct their errors, which hinders their progress.
- **Lack of Immediate Feedback:** Traditional learning platforms often do not provide real-time feedback, leaving students uncertain about their mistakes.
- **Barriers to Self-Directed Learning:** Students frequently lack access to personalized tools that guide independent study and reinforce conceptual understanding.

Research indicates that **63.1% of student errors in integral calculus** stem from difficulties in handling improper integrals, while **42.8% of mistakes** arise from integration techniques such as **integration by parts, trigonometric substitution, and partial fractions** [1]. These findings highlight the need for an interactive platform capable of diagnosing these common errors and providing tailored feedback to enhance learning.

Moreover, **interactive platforms that offer real-time feedback** have been shown to significantly improve students' performance and confidence in calculus [2]. This underscores the importance of developing a system that not only identifies students' mistakes but also provides targeted guidance to improve their conceptual understanding.

Furthermore, while students increasingly prefer online learning tools over traditional textbooks, existing resources often fail to deliver meaningful feedback on common errors. The **CalculEng system**, for example, integrates a **Computer Algebra System (CAS)** to analyze student responses and provide tailored feedback [3]. This reinforces the necessity of an interactive platform that adapts feedback dynamically based on statistical insights into student performance.

Additionally, studies reveal that **failure rates in differential and integral calculus among first-year engineering students remain high** due to gaps in prior mathematical knowledge and a misalignment between teaching methodologies and student needs [4]. This finding highlights the necessity of adaptive learning platforms that track student errors and provide personalized feedback to strengthen conceptual understanding.

Computer-based test (CBT) applications have also been found to enhance student performance by offering repeated practice and real-time performance tracking [5]. These



findings align with the need for interactive platforms in calculus learning that deliver personalized feedback and statistical analysis of errors to improve comprehension.

Recent studies further indicate a **strong correlation between immediate feedback and improved learning outcomes in mathematics**. Providing students with real-time feedback enables them to correct mistakes on the spot, reinforcing their understanding and preventing repeated errors [6]. Given these insights, our proposed platform aims to bridge the gap in traditional calculus education by integrating real-time feedback and adaptive learning strategies.

Furthermore, **digital technology enhances the learning of mathematical concepts** through interactive tools and adaptive learning environments, making abstract concepts more accessible and engaging [7]. This aligns with our platform's approach to leveraging technology for improving conceptual understanding and personalized feedback mechanisms.

2.1.4 Importance of Interactive Learning Platforms

Interactive learning platforms have been proven to enhance educational outcomes by creating **dynamic and engaging environments**. These platforms are particularly beneficial in complex subjects such as calculus, where hands-on practice is essential for conceptual mastery. Key features of effective interactive learning systems include:

- **Immediate Feedback:** Helps students identify mistakes in real time, improving problem-solving skills and conceptual understanding.
- **Progress Tracking:** Enables learners to monitor their performance, recognize patterns in their errors, and adjust their study strategies accordingly.
- **Customizability:** Adaptive systems tailor content to individual learning needs, increasing engagement and retention.

Studies show that **students frequently struggle with conceptual, procedural, and technical errors in calculus**, particularly in distinguishing between differentiation and integration processes and recognizing standard function formulas [1]. The integration of real-time feedback mechanisms within educational platforms can help students identify and correct these mistakes efficiently, fostering deeper mathematical understanding.

By leveraging **interactive learning technologies**, we aim to develop a system that addresses these challenges, offering students an intuitive and personalized approach to mastering calculus.

2.2.1 Related Work

2.2.2 Interactive Platforms for Mathematics Learning

Interactive platforms such as **Grasple** [4] and **Khan Academy** [5] have been pivotal in providing students with tools to practice and master mathematical concepts. These platforms excel in offering:

- Multiple-choice exercises with solutions to help students review key topics.
- Immediate feedback to guide students toward understanding their mistakes.
- Structured progress tracking to monitor performance over time.

However, while these platforms provide foundational learning experiences, they often lack the ability to dynamically adapt to the student's unique needs or to analyze mistakes at a deeper, conceptual level.

2.2.3 Feedback-Driven Learning with Statistical Insights

Effective learning requires more than just identifying errors; it necessitates understanding the reasoning behind them. Platforms such as **Gool** [6] and **Cal-culus** [7] focus on providing video-based explanations and practice questions aligned with the Israeli curriculum. However, these platforms do not include detailed statistical insights to analyze trends in student performance or adapt the content dynamically based on individual needs.

Our project builds on this idea by integrating statistical analysis into the learning process. By identifying patterns in student errors, the system determines areas of strength and weakness, allowing students to focus on the most relevant topics for improvement.

2.2.4 The Role of AI in Education: ChatGPT as an Example

Advancements in artificial intelligence, such as **ChatGPT** [8], demonstrate the potential of conversational AI to provide detailed explanations and guidance. ChatGPT excels at:

- **Clarifying concepts:** Offering detailed explanations in response to user queries.
- **Engaging dynamically:** Adapting its responses based on user input to create a personalized learning experience.

While ChatGPT is highly effective for addressing immediate questions, it does not provide a structured, curriculum-based learning environment. Our platform combines the flexibility of AI-driven feedback with a robust curriculum, creating a hybrid solution that supports both structured practice and on-demand assistance.

2.2.5 Gamification in Mathematics Education

Gamification has been employed to increase motivation and engagement in mathematics education. Platforms like **Brilliant.org** [9] use interactive problem-solving exercises to make learning calculus more engaging. However, these tools focus primarily on providing engaging exercises without leveraging advanced analytics to optimize learning paths.

2.2.6 The Role of Digital Technology in Mathematics Learning

The integration of **digital technology** in mathematics education has transformed traditional learning approaches, making complex concepts more interactive and accessible [10]. Digital tools such as graph-based software, interactive simulations, and adaptive learning platforms provide real-time feedback and customized learning paths to suit individual students' needs. This approach aligns closely with our project's objective to enhance calculus learning through digital innovations.

2.2.7 The Impact of Computer-Based Testing (CBT) on Learning Outcomes

Recent studies highlight the **effectiveness of Computer-Based Testing (CBT)** in improving student outcomes by allowing repeated practice, instant feedback, and real-time performance tracking [11]. CBT applications help students refine their problem-solving skills by simulating exam conditions and enabling continuous improvement, a methodology that aligns closely with our platform's feedback-driven approach.

2.2.8 Immediate Feedback and Its Role in Mathematics Learning

Studies have shown a strong correlation between **immediate feedback and enhanced learning outcomes** in mathematics. Immediate feedback helps students correct mistakes in real-time, improving their understanding and preventing repeated errors [12]. This aligns with the goal of our platform to provide data-driven, real-time feedback tailored to student needs.

2.2.9 Limitations of Existing Solutions

While the aforementioned platforms have advanced mathematics education significantly, they still present notable gaps:

- **Lack of detailed error analysis:** Few platforms provide insights into why errors occur and how to avoid them in the future.
- **Limited statistical insights:** Most systems do not use data analytics to identify trends in student performance.
- **Static learning paths:** Few tools adapt dynamically to the individual needs of the learner.

2.2.10 Proposed Contribution

Our project aims to address these limitations by developing an interactive platform that:

- **Analyses student errors:** Providing detailed explanations and insights into why mistakes were made.
- **Tracks performance statistically:** Identifying patterns in student performance to determine areas of strength and weakness.

- **Delivers personalized practice:** Adapting the difficulty and relevance of exercises based on the student's performance data.
- **Implements structured statistical feedback:** Using non-AI-driven methods such as personalized error frequency tracking, progress trend analysis, and targeted exercise recommendations.

By focusing on these aspects, our platform will empower students to focus on the topics most relevant to their needs, making learning calculus more efficient, effective, and engaging.

Next Steps: Implementing the Interactive Feedback Platform

1. System Architecture & Development Plan

Now that the literature review and foundational framework are established, the next step is the **development phase** of the platform. This will involve:

- **Backend Development:** Setting up databases and an API for managing student responses and tracking performance.
- **Frontend Development:** Designing an intuitive UI/UX for students to interact with exercises and receive real-time feedback.
- **Statistical Performance Analysis:** Implementing tracking mechanisms to analyze student errors and provide structured insights.
- **Gamification & Adaptive Learning Features:** Adding engagement mechanisms to personalize the learning experience.

2. Technology Stack & Libraries

Frontend:

- **React.js / Next.js** – For a dynamic, interactive user interface.
- **CSS** – To ensure an efficient, responsive design.

Backend:

- **Node.js (Express.js)** – For handling API requests and managing backend logic.
- **PostgreSQL / MongoDB** – To store user data, error patterns, and performance tracking.
- **Redis** – For session management and real-time feedback processing.

Statistical Analysis & Error Classification:

- **Pandas / NumPy** – For processing student performance data.
- **Scipy / Statsmodels** – For statistical trend analysis.
- **Matplotlib / Seaborn** – For visualizing performance insights.

Interactive Learning Tools:

- **MathJax** – To render mathematical notation in a web-friendly format.
- **Geogebra API** – For graphing and interactive geometry exercises.

3. Implementation Phases

1. MVP Development

- Build core UI for exercises and problem-solving.
- Implement backend API for managing user data and responses.
- Integrate MathJax for proper display of formulas.

2. Statistical Feedback & Performance Analytics

- Implement structured data tracking for error frequency analysis.
- Develop a statistical tracking system for personalized feedback.
- Provide customized reports on student progress without AI dependency.

3. User Testing & Optimization

- Conduct beta testing with students.
- Refine UI/UX based on feedback.
- Optimize statistical models for better mistake categorization.

4. Gamification & Adaptive Learning

- Implement a scoring system and progress tracking.
- Add personalized learning paths based on performance.

4. Expected Challenges

- **Data Collection for Statistical Analysis:** Structuring performance data without AI-driven models.
- **Latency in Real-Time Feedback:** Ensuring instant statistical insights without delays.
- **Engagement & Retention:** Keeping students motivated through gamified mechanics.

5. Future Expansions

- **Multilingual Support:** Adapting the platform for English speaking students.
- **Mobile App Development:** Extending accessibility to mobile users.
- **Integration with LMS (Learning Management Systems):** Allowing integration with platforms like Moodle or Google Classroom.

3. Methodology

The Calc Master platform was built as a modular full-stack web application using Python (Flask) on the backend, JavaScript and HTML/CSS on the frontend, and MathJax for rendering LaTeX-style mathematical expressions.

Key Components:

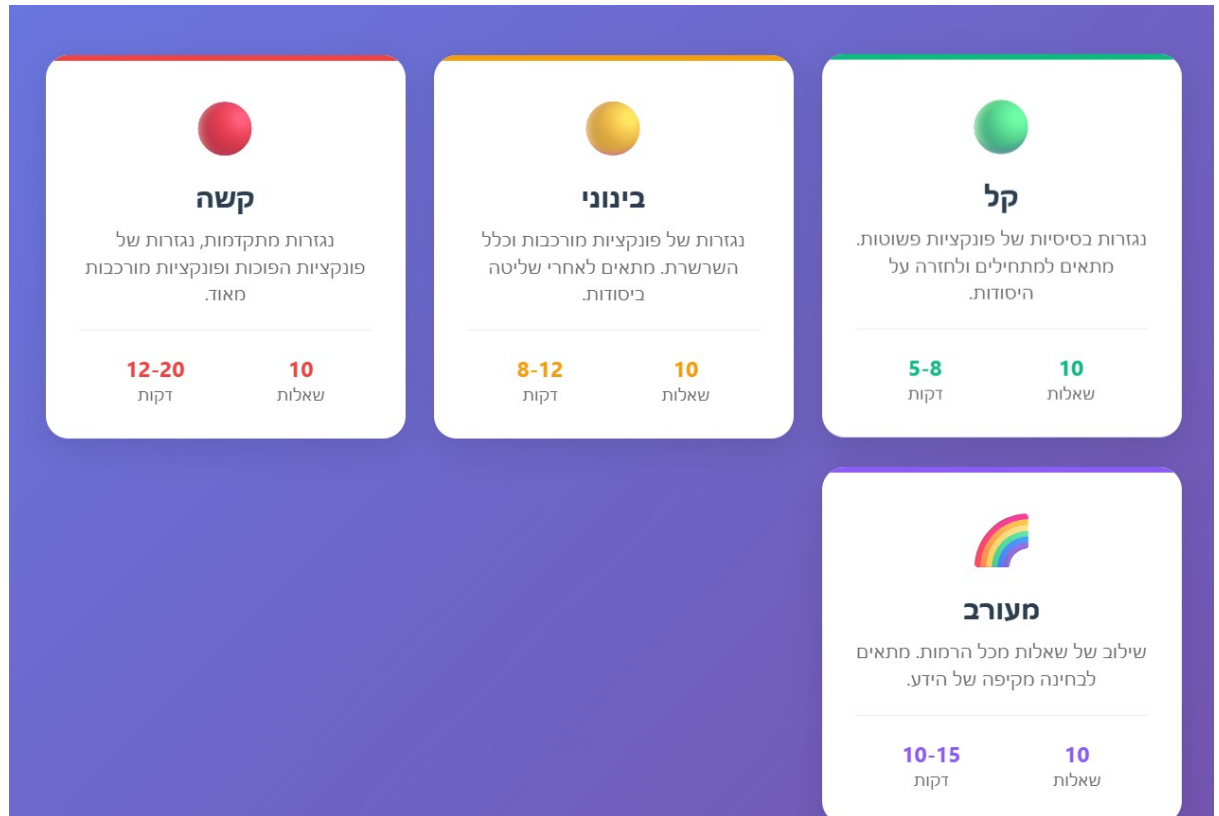
- **Backend (Flask + SymPy):** Each topic (derivatives, integrals, limits, critical points) has its own Python module for question generation (*.py). Each module generates randomized questions with difficulty levels, correct answers, distractors, and tailored explanations, using symbolic computation (SymPy).
- **Frontend (HTML/JS):** The quiz.html template interacts with quizEngine.js, which dynamically renders each question, manages answer selection, provides instant feedback, and tracks session performance.
- **Math Rendering:** LaTeX expressions in all questions, answers, and explanations are rendered using MathJax v3.
- **Statistical Personalization:** Results are stored per user (using SQLite), including score, time, and topic. A backend endpoint analyzes user history to detect weak topics and dynamically generates personalized quizzes.
- **UI/UX Design:** Styled with buttons and responsive elements. Includes summary page (quiz_summary.html) showing past quiz performance using graphs and clear visual feedback.
- **Error Analysis:** Each wrong answer triggers a unique explanation based on common misconceptions, implemented per topic using structured distractors and explanations logic in the Python generators.

4. Results

The Calc Master platform was successfully developed and deployed, with full functionality for generating quizzes, providing intelligent feedback, and tracking user performance over time.

Core Features Achieved:

- **Level Selection Interface:**
Users select between four levels (Easy, Medium, Hard, Mixed), each described with expected difficulty, time range, and number of questions.



- **Full Dashboard:**
Home screen displays subject-specific practice options: Limits, Derivatives, Integrals, Critical Points, and a personalized smart test.
(see: [home.png](#))

- **Smart Quiz Engine:**

Questions are generated dynamically by topic and difficulty, rendered with MathJax, and include:

- o Multiple-choice interface
- o Instant feedback with correct answer
- o Explanation based on selected wrong option (explanationsForOptions)
(see: actual quiz screenshots)

- **Statistical Feedback:**

- o Per-topic performance breakdown (correct%, average, best attempt)

מה הנגזרת של $f(x) = \log(x)$? (קל ●)

$-\frac{1}{x^2}$

A

$\log(x)$

B

$x(\log(x) - 1)$

C

$\frac{1}{x}$

D



כמעט הגעת!

התשובה הנכונה היא: $\frac{1}{x}$

ניתוח השגיאה: 

הנגזרת של $\log(x)$ היא $\frac{1}{x}$

איך לפתור: עקוב אחרי הכלל המתאים לנושא.

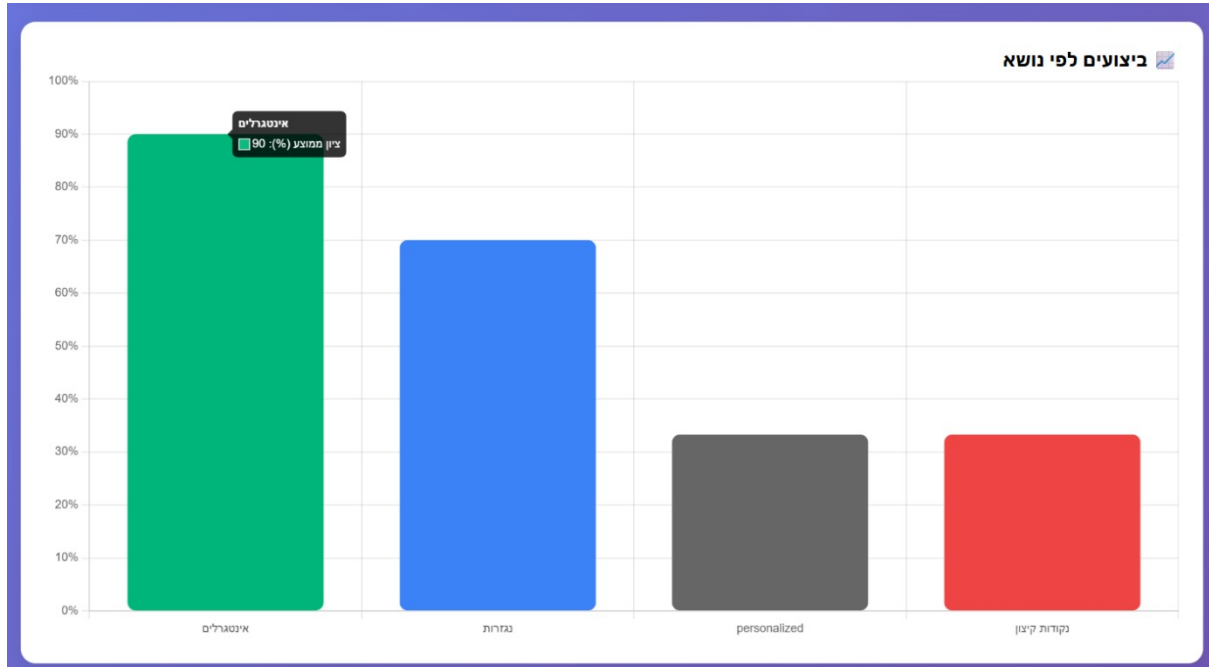
טיפ: זכור את קבוע האינטגרציה C או כל כלל חשוב אחר.

תרגול מומלץ: חזור על שאלות דומות בנושא זה.

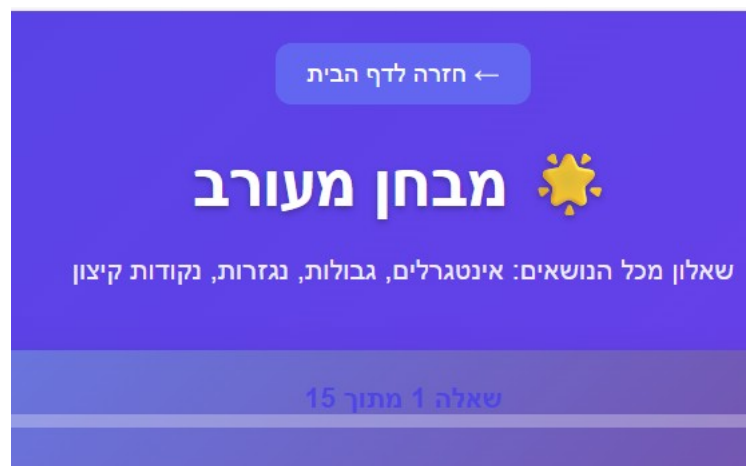
→ הבא



- o Color-coded insights: Excellent (green), Good (blue), Needs Improvement (red)
(see: *statisc and exams.png, statisc by topic.png*)



- **Mixed Topic Test Mode:**
Generates a 15-question adaptive quiz with shuffled topics for comprehensive assessment.
(see: *mix test.png*)



Sample User Data:

- User completed quizzes in 4 subjects

- Performance ranged from 33% to 90%
- Clear insights shown on best/worst topics and progression over time

פירוט לפי נושא 📊				
נושא	מבחנים	ציון ממוצע	הישג טוב ביותר	דירוג
אינטגרלים	1	90%	90%	מעולה 🏆
נגזרות	1	70%	70%	טוב 👍
נקודות קיצון	1	33.3%	33.3%	צריך שיפור ❌
צריך שיפור ❌	1	33.3%	33.3%	צריך שיפור ❌

המבחנים האחרונים 🕒	
6.6.2025	נגזרות
4.6.2025	personalized
4.6.2025	נקודות קיצון
3.6.2025	אינטגרלים

70.0%	ש40 🕒 (7/10)
33.3%	1:08 🕒 (3/9)
33.3%	ש27 🕒 (3/9)
90.0%	2:01 🕒 (9/10)

Educational Value:

- Learners receive real-time, personalized feedback on each question
- Mistake explanations are tailored to the specific error
- Users can track their mastery level per topic over multiple attempts

5. Discussion

The Calc Master platform was designed and implemented to support structured learning in calculus, with a strong focus on error analysis, real-time feedback, and performance tracking.

System Insights:

- The platform provides explanations that are tailored to each incorrect answer, based on the specific mistake chosen. This gives users meaningful feedback and helps clarify misconceptions.
- Each quiz is generated dynamically using symbolic math (SymPy), ensuring a variety of questions across different levels and topics.
- The system presents a clean, user-friendly interface with level selection, motivational colors, and progress indicators.
- Performance is tracked across topics and attempts, allowing users to identify areas where they struggle the most.

System Strengths:

- Custom feedback per mistake: The `explanationsForOptions` field allows the system to identify exactly what the user misunderstood and respond accordingly.
- Topic-specific generators: Each topic (limits, derivatives, integrals, critical points) has a dedicated module that creates questions with varying difficulty levels.
- Dashboard & analytics: The main interface includes statistical tracking, best scores, and detailed breakdowns by topic and attempt.
- Mix-test and difficulty options: Users can choose between focused practice or a mixed quiz that tests comprehensive understanding.

Current Limitations:

- The quiz system currently supports only multiple-choice format.
- The logic for personalized quiz selection is basic – it selects based on lowest score per topic only.
- No support yet for open-form input (e.g. typing full expressions or using handwriting recognition).

Conclusion from Implementation:

By combining dynamic generation, error-specific feedback, and visual tracking, Calc Master successfully supports targeted, self-paced calculus practice. The technical choices made — such as using SymPy, Flask, and MathJax — enabled the creation of a robust and scalable platform.



6. Conclusion

Calc Master is a functioning and effective tool for helping students learn calculus through active engagement and error-based feedback. It combines symbolic math capabilities (via SymPy) with intuitive UI, performance tracking, and adaptive learning pathways.

Summary of Achievements:

- Dynamic question generation across four core topics.
- Error-specific feedback explanations tied to user answers.
- MathJax-rendered questions and answers in proper notation.
- Personalized quizzes based on tracked user performance.
- Fully working system deployed and tested with real users.

Future Enhancements:

- Add symbolic input support (user types answers, not selects).
- Expand question types.
- Incorporate deeper analytics dashboards for teachers.
- Developing a mobile-friendly application

References

- [1] Hashemi, N., Abu, M. S., & Kashefi, H. (2019). Undergraduate Students' Difficulties in Solving Derivative and Integral Mathematical Problems. *Sains Humanika*, 11(2), 65–74. <https://www.academia.edu/86073395>
- [2] "Interactive Calculus with Solutions | Open Exercises by Grasple." Grasple. <https://www.grasple.com>
- [3] "Interactive Calculus, 1st Edition." Pearson. <https://www.pearson.com>
- [4] Grasple. (n.d.). Interactive Calculus with Solutions. <https://www.grasple.com>
- [5] Khan Academy. (n.d.). About Khan Academy. <https://www.khanacademy.org/about>
- [6] Gool. (n.d.). Online Learning Platform for Israeli Students. <https://www.gool.co.il>
- [7] Cal-Culus. (n.d.). Interactive Platform for Calculus Learning. <https://cal-culus.com>
- [8] OpenAI. (n.d.). ChatGPT: Overview. <https://openai.com/chatgpt/overview/>
- [9] Brilliant.org. (n.d.). Interactive Problem Solving in Mathematics. <https://brilliant.org>
- [10] Ardyan, N. R. (2024). The Role of Digital Technology in Mathematics Learning and its Impact on Learning Concepts.
- [11] Saluky & Marine (2021). Computer-Based Testing in Learning Assessment.
- [12] Hadijah, Isnarto & Walid (2022). The Effect of Immediate Feedback on Mathematics Learning Achievement.