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Review Article

Integration of TI 84 and TI 89 Model Graphing Calculators in Mathematics Education: Precalculus Instruction Using the TPACK Framework

Rusen MEYLANI [1,*]

[1] *Dicle University, Diyarbakır, Türkiye, rusen.meylani@dicle.edu.tr*

[*] *Corresponding Author: rusen.meylani@dicle.edu.tr*

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Abstract

Integrating TI 84 and TI 89 model graphing calculators into Precalculus instruction through the Technological Pedagogical Content Knowledge (TPACK) framework presents a significant advancement in mathematics education. This study explores how these calculators enhance mathematics teaching practices and improve student learning outcomes by integrating technology, pedagogy, and content knowledge via the TPACK framework. The study synthesizes literature through a qualitative theoretical approach to identify the benefits and challenges of graphing calculators in Precalculus. The findings highlight the calculators' role in increasing student engagement, enhancing conceptual understanding, and supporting problem-solving skills. However, challenges such as potential overreliance on technology, accessibility issues, and the need for professional development are also addressed. The study emphasizes the importance of strategic planning and implementation to maximize the benefits of graphing calculators while addressing these challenges. Recommendations for policy and practice include providing equitable access to technology, incorporating technology literacy into the curriculum, and developing innovative assessment methods. Future research directions are suggested to explore longitudinal impacts, effective pedagogical strategies, and integration with other emerging technologies.

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Introduction

Background

Technology is a game-changer in modern education, revolutionizing teaching and learning practices, particularly mathematics. Its integration into education has become increasingly important due to its potential to enhance student engagement, facilitate personalized learning experiences, and improve overall academic performance (Filges et al., 2022). With the advent of digital tools and resources, educators can leverage technology to

create interactive and dynamic learning environments that cater to diverse learning styles and abilities, sparking excitement and intrigue among students.

Significance of Precalculus

Precalculus, a cornerstone in the mathematics curriculum, is significant as it bridges algebra and calculus, laying the foundation for advanced mathematical concepts and problem-solving skills. This role underscores the importance and relevance of the work of educators in this field. Mastery of precalculus is essential for students pursuing Science, Technology, Engineering, and Mathematics (STEM) fields, as it provides the necessary mathematical background to tackle complex topics in calculus, physics, and engineering (Wade et al., 2023). Moreover, precalculus equips students with valuable critical thinking and analytical reasoning abilities in various academic and professional pursuits.

Role of Graphing Calculators

Graphing calculators, such as the TI-84 and TI-89 models, enhance mathematical understanding by providing students with a visual representation of mathematical concepts. These calculators offer functionalities that allow students to graph functions, analyze data, and solve equations efficiently, enabling them to explore mathematical relationships dynamically and interactively (Alrwaished, 2024). The use of graphing calculators not only enhances students' computational skills but also fosters a deeper conceptual understanding of mathematical principles.

Purpose of the Study

This study aims to investigate the integration of TI-84 and TI-89 graphing calculators in precalculus instruction using the TPACK framework. The research question revolves around how incorporating graphing calculators within the TPACK framework enhances teaching practices and improves student learning outcomes in precalculus. The objectives of the study include evaluating the impact of graphing calculators on student engagement, assessing the effectiveness of pedagogical strategies in conjunction with technology integration, and exploring best practices for educators to optimize the use of graphing calculators in precalculus instruction (Chai et al., 2020).

Theoretical Framework: TPACK

Overview of TPACK

The TPACK framework is a conceptual model that integrates three essential components: Technological Knowledge (TK), Pedagogical Knowledge (PK), and Content

Knowledge (CK) to guide educators in effectively integrating technology into teaching practices (Raihanah, 2024).

TK: TK refers to teachers' understanding of using technology tools and resources effectively in educational settings. It encompasses knowledge of various technological tools, software applications, and digital resources that enhance teaching and learning experiences (Deng, 2023).

CK: CK pertains to teachers' expertise in the subject matter they are teaching, including the depth of knowledge in specific content areas such as mathematics, science, or language arts (Redmond & Lock, 2019).

PK: PK focuses on teachers' understanding of instructional strategies, classroom management techniques, and assessment practices to facilitate effective teaching and learning (Susanto, 2021).

Intersections of TPACK

The intersection of these three knowledge domains forms the core of the TPACK framework, which emphasizes integrating technology, pedagogy, and content knowledge to enhance teaching practices and improve student learning outcomes (Chophel, 2021). By combining TK, PK, and CK, educators create meaningful learning experiences that leverage technology to support and enhance the delivery of content knowledge pedagogically soundly (Edouard, 2023). The TPACK framework provides a structured approach for teachers to develop a holistic understanding of effectively integrating technology into their instructional practices while focusing on content mastery and pedagogical effectiveness (Purwanto et al., 2020).

Literature Review

Historical Context

The evolution of graphing calculators in mathematics education has significantly developed over the years, revolutionizing the way mathematical concepts are taught and learned. Initially introduced in the 1980s, graphing calculators quickly gained popularity in educational settings due to their ability to graph functions, solve equations, and perform complex calculations efficiently (Othman & Maat, 2020). These calculators gave students a visual representation of mathematical concepts, allowing for a deeper understanding of abstract mathematical ideas and facilitating problem-solving in various mathematical disciplines.

Current Trends

In recent years, a growing body of research has focused on using graphing calculators in precalculus education. Studies have highlighted the benefits of incorporating graphing calculators in precalculus instruction, emphasizing their role in enhancing students' mathematical understanding and problem-solving skills (Othman & Maat, 2020). Research by Thompson and Wallach (2023) explored integrating open educational resources in precalculus courses, demonstrating how technology tools like graphing calculators support student learning and engagement. By leveraging graphing calculators in precalculus instruction, educators create interactive and dynamic learning experiences that cater to diverse learning styles and promote conceptual understanding in mathematics.

TPACK in Education

Applying the TPACK framework in teaching mathematics has garnered significant attention in educational research. Studies have examined how the TPACK framework guides educators in effectively integrating technology, pedagogy, and content knowledge to enhance teaching practices and improve student learning outcomes (Othman & Maat, 2020). A systematic literature review by Othman and Maat (2020) identified key themes and research methods used in studies focusing on the TPACK framework. By applying the TPACK framework, educators develop a comprehensive understanding of leveraging technology tools like graphing calculators to support content delivery, engage students, and promote deeper learning in mathematics.

Literature on TPACK in education emphasizes the importance of teachers' proficiency in integrating technology, pedagogy, and content knowledge to create meaningful student learning experiences (Othman & Maat, 2020). Studies by Setiawan et al. (2018) and Funk et al. (2022) explored how teacher educators model TPACK to create multimedia resources and promote active learning in mathematics classrooms, highlighting the transformative potential of the TPACK framework in enhancing teaching practices. The TPACK framework empowers teachers to create engaging and interactive learning environments that foster student success in mathematics and other subjects by equipping educators with the knowledge and skills to effectively integrate technology into their teaching practices.

Methodology

The methodology section will describe the theoretical approach and research design used to explore the integration of TI 84-89 graphing calculators into Precalculus instruction through the lens of the TPACK framework. This involves thoroughly exploring research design, data sources, and analytical methods.

Research Design

The research design of this study is centered on a qualitative theoretical approach, emphasizing conceptual analysis and literature synthesis to explore the integration of TI calculators into Precalculus instruction using the TPACK framework. The primary objective is to develop a comprehensive understanding of how technology, pedagogy, and content knowledge intersect in the context of Precalculus education. This study employs the TPACK framework as the primary analytical lens. TPACK is a widely recognized model that facilitates technology integration in education by focusing on the interplay between technological, pedagogical, and content knowledge.

The research adopts a qualitative approach, utilizing theoretical analysis and literature review to examine how TI calculators are effectively utilized in Precalculus instruction. This method allows for a nuanced understanding of the effective use of technology to enhance teaching and learning. The exploratory study aims to generate insights and hypotheses about best practices and strategies for integrating TI calculators using the TPACK framework. It seeks to identify potential benefits, challenges, and areas for further research. A conceptual map is developed to illustrate how the components of the TPACK framework (technological, pedagogical, and content knowledge) interact with using TI calculators in teaching Precalculus. This visual representation helps clarify theoretical relationships and guides the analysis.

Data Sources

The study relies on a comprehensive collection of academic literature, educational resources, and case studies to examine the integration of TI 84 and TI 89 graphing calculators within the TPACK framework. The selected data sources provide insights into the technological, pedagogical, and content knowledge aspects of using graphing calculators in Precalculus instruction.

- *Textbooks on Precalculus and Graphing Calculators:* Several textbooks covering Precalculus concepts and the functionalities of TI 84 and TI 89 calculators serve as foundational resources. These books offer detailed explanations of calculator operations, graphing techniques, and their application in mathematical problem-solving (Rodríguez, 2019).
- *Peer-Reviewed Journal Articles:* Scholarly research articles discussing the use of graphing calculators in mathematics education and the application of the TPACK framework were analyzed. Studies have highlighted the impact of graphing calculators on student engagement, conceptual understanding, and problem-solving abilities (Othman & Maat, 2020; Chai et al., 2020). Additionally, articles exploring educators' technological pedagogical content knowledge (TPACK) inform the study's analysis (Deng, 2023).
- *Case Studies on TI Calculator Integration:* Case studies from various educational institutions provide real-world examples of successful integration of TI 84 and TI 89 calculators in mathematics instruction. These cases illustrate how teachers implement calculators in the classroom and highlight effective strategies and challenges (Costa et al., 2021).
- *Reports and White Papers from Educational Organizations:* Reports from technology providers such as Texas Instruments and research institutes contribute additional insights. These reports discuss the effectiveness of graphing calculators in improving student performance and present recommendations for integrating technology in mathematics education (González et al., 2022).
- *Conference Proceedings on Educational Technology:* Proceedings from mathematics education and educational technology conferences offer recent developments and innovative practices related to integrating graphing calculators within the TPACK framework (Setiawan et al., 2018).

The data synthesis involves identifying key themes, trends, and findings across these sources, ensuring a thorough examination of the role of TI 84 and TI 89 calculators in Precalculus education.

Analysis

The analysis process in this study involves synthesizing data from multiple sources to evaluate the integration of TI 84 and TI 89 graphing calculators within the TPACK

framework. Various qualitative data analysis tools and techniques were used to examine trends, themes, and relationships in the literature.

- *Literature Review and Thematic Analysis:* A systematic literature review was conducted to identify key themes, trends, and findings related to the use of graphing calculators in Precalculus instruction and the TPACK framework. Thematic analysis was applied to categorize and interpret data, allowing for a structured exploration of how these calculators impact student engagement, conceptual understanding, and pedagogical strategies (Braun & Clarke, 2006).
- *Framework Mapping:* The study employed framework mapping to align the features and functionalities of TI 84 and TI 89 calculators with the components of the TPACK framework. This mapping process helped identify how specific calculator functions (e.g., graphing, equation solving, data analysis) align with TK, PK, CK as conceptualized by Mishra and Koehler (2006).
- *Qualitative Content Analysis:* Qualitative content analysis was used to examine how educators integrate graphing calculators in instructional settings. This method involved coding and categorizing data from case studies, research articles, and educational reports to identify common instructional strategies, challenges, and best practices (Elo & Kyngäs, 2008).
- *Comparative Case Study Approach:* A comparative case study approach was applied to analyze multiple case studies on the integration of TI calculators in Precalculus. This approach provided insights into different teaching contexts, instructional methods, and student outcomes, enabling a broader understanding of how technology supports mathematics education (Yin, 2018).
- *Conceptual Analysis:* Conceptual analysis was employed to explore the theoretical intersections between the TPACK components and the practical use of graphing calculators in Precalculus instruction. This method critically examined how technology enhances pedagogical approaches and facilitates the teaching of complex mathematical concepts (Neuendorf, 2017).
- *Thematic Coding:* Patterns and themes in the literature were identified, allowing for systematic analysis and visualization of connections between different elements of the TPACK framework (Bazeley & Jackson, 2013).

Findings

This study explored the integration and application of TI-84 and TI-89 calculators in Precalculus education, emphasizing their impact on technological, content, and pedagogical knowledge. Findings are organized into four key themes (Figure 1).

The first theme, Application of TI-84/89 Calculators in Precalculus, focuses on three aspects. Technological Knowledge highlights the advanced functionalities of these calculators, such as graphing, data analysis, and programming, which enhance mathematical understanding. Content Knowledge emphasizes how these calculators help visualize and solve key Precalculus concepts, including functions, transformations, and equations. Pedagogical Strategies discuss methods for integrating calculators into teaching, such as gradually introducing functionalities, encouraging collaborative problem-solving, and applying real-world scenarios to engage students.

The second theme, Integration within the TPACK Framework, explores how these calculators align with the TPACK framework. Technological Pedagogical Knowledge (TPK) examines the use of calculators to create dynamic and interactive learning experiences. Technological Content Knowledge (TCK) addresses how calculators support the visualization and exploration of mathematical content. Pedagogical Content Knowledge (PCK) focuses on instructional strategies that enhance students' conceptual understanding by effectively combining pedagogy and content with technology.

The third theme, Benefits and Challenges, addresses the advantages and obstacles associated with using graphing calculators in education. Benefits include enhanced student engagement, improved understanding of abstract mathematical concepts through visualization, and support for real-world applications of mathematics. However, challenges such as overdependence on technology, accessibility issues due to cost, and the need for adequate teacher and student training are also identified.

The fourth theme, Case Study: *PreCalculus with TI 84–89* (Meylani, 2024) examines a book that demonstrates the application of these calculators in Precalculus instruction. The book includes chapters covering topics such as TI-84 basics, graphing techniques, sample problems, and features of the TI-89. The analysis of the book through the TPACK framework highlights its focus on Technological Knowledge (TK), including calculator functions and graphing capabilities; Content Knowledge (CK), which includes comprehensive coverage of Precalculus topics and sample problems; and Pedagogical Knowledge (PK), which

emphasizes instructional strategies and learning progressions. The integration of the book's content within the TPACK framework further demonstrates the effective use of technology, pedagogy, and content knowledge in enhancing teaching and learning.

This framework provides a comprehensive understanding of how TI-84 and TI-89 calculators can transform Precalculus education, fostering deeper learning and more effective teaching practices.

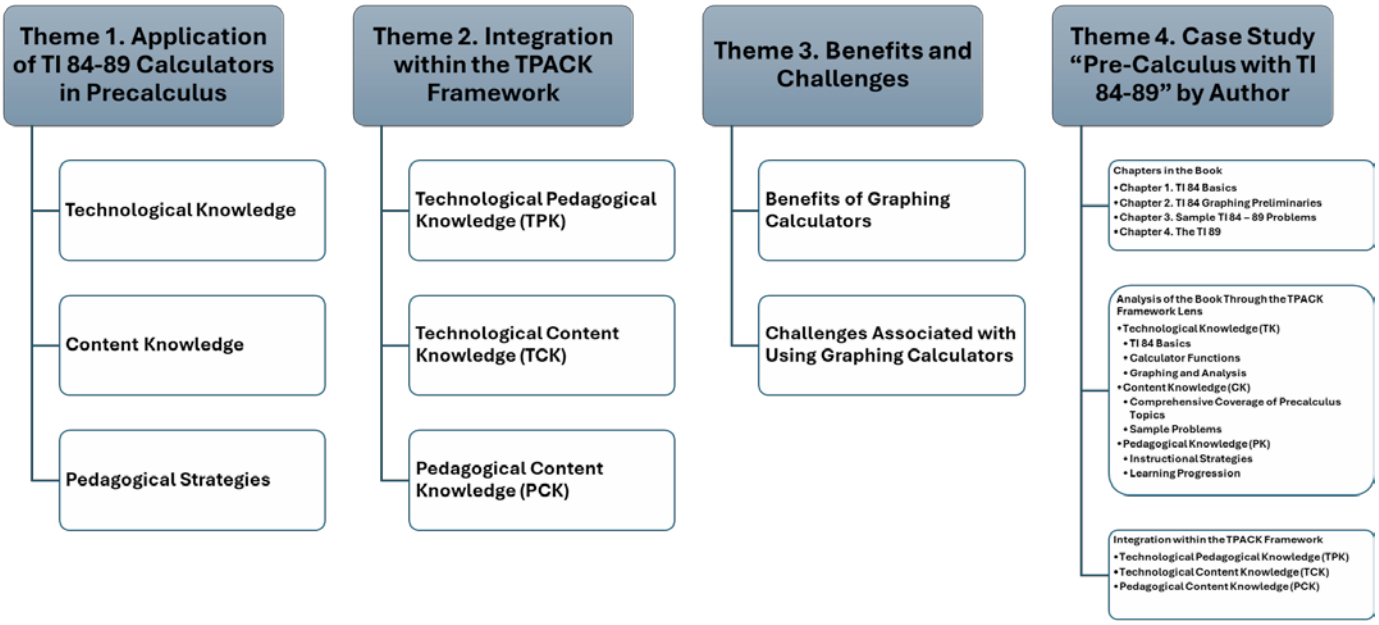


Figure 1. Main themes and sub-themes that resulted from the qualitative analysis.

Results

Theme 1. Application of TI 84-89 Calculators in Precalculus

Applying TI-84 and TI-89 calculators in Precalculus gives students powerful tools that enhance their understanding of complex mathematical concepts through advanced functionalities. These calculators offer capabilities such as graphing equations, solving complex problems, and performing statistical analyses, essential for developing mathematical understanding and problem-solving skills in Precalculus. These calculators' graphical interface and programmability allow students to visualize and interact with mathematical concepts, fostering a more profound comprehension of abstract ideas and supporting active learning through simulations and interactive activities.

TK

In exploring the application of TI-84 and TI-89 calculators in precalculus, it is essential to delve into the functionalities and features of these calculators that are

particularly relevant to precalculus education. The TI-84 and TI-89 calculators offer various capabilities that significantly enhance students' mathematical understanding and problem-solving skills. These calculators provide functions for graphing mathematical equations, solving complex equations, analyzing data, and performing statistical calculations (Wu et al., 2020). The graphical interface of these calculators allows students to visualize mathematical concepts, such as functions, transformations, and intersections, aiding in comprehending abstract mathematical ideas (Wu et al., 2020). Additionally, the programmability of these calculators enables students to explore mathematical concepts through simulations and interactive activities, fostering a deeper understanding of precalculus topics.

CK

In terms of content knowledge, key precalculus concepts benefit significantly from the use of graphing calculators. Graphing functions, a fundamental aspect of precalculus, are effectively demonstrated and analyzed using the graphing capabilities of TI-84 and TI-89 calculators. Students visualize the behavior of functions, explore transformations, and identify key features such as intercepts, asymptotes, and extrema with ease using these calculators (Wu et al., 2020). Moreover, solving equations, whether algebraic, trigonometric, or exponential, becomes more accessible and interactive with the equation-solving functionalities of these calculators. Students verify solutions, explore multiple representations of equations, and gain a deeper insight into the solutions of complex equations through graphical representations (Wu et al., 2020). Analyzing data, another crucial aspect of precalculus is streamlined with the statistical functions of these calculators, allowing students to perform regression analysis, hypothesis testing, and data visualization efficiently.

Pedagogical Strategies

Effective pedagogical strategies are vital in integrating graphing calculators in the precalculus classroom. One such strategy is gradually introducing calculator functionalities, starting with basic operations and progressing to more advanced features as students become familiar with the technology (Wu et al., 2020). Encouraging students to explore mathematical concepts independently using the calculators promotes active learning and critical thinking. Incorporating collaborative activities where students work in groups to solve problems using graphing calculators enhances peer learning and communication skills. Providing real-world applications of precalculus concepts that require graphing calculators

also increases student engagement and motivation (Wu et al., 2020). Furthermore, integrating formative assessment techniques that leverage the calculators' capabilities to provide immediate feedback on student understanding helps teachers tailor instruction to meet individual student needs effectively.

Theme 2. Integration within the TPACK Framework

Integrating TI-84 and TI-89 calculators within the TPACK framework highlights the effective use of technology in enhancing pedagogical practices and content delivery. Through Technological Pedagogical Knowledge (TPK), educators utilize these calculators to create interactive learning experiences that engage students in exploring mathematical concepts visually and dynamically. Furthermore, Technological Content Knowledge (TCK) is demonstrated by how calculators support the visualization and exploration of Precalculus content, allowing students to engage deeply with the subject matter. At the same time, Pedagogical Content Knowledge (PCK) focuses on strategies that facilitate learning through guided exploration, collaboration, and real-world applications.

TPK

In integrating TI-84 and TI-89 calculators within the TPACK framework, it is crucial to understand how these calculators enhance teaching methods through TPK. TPK involves utilizing technology tools effectively to support pedagogical practices and enhance content delivery. When using graphing calculators in precalculus instruction, educators leverage TPK by incorporating interactive activities that allow students to explore mathematical concepts visually. By guiding students in graphing functions, analyzing data, and solving equations using calculators, teachers create engaging learning experiences that promote active exploration and deeper understanding of precalculus concepts (Başer et al., 2016).

TCK

Moreover, TCK plays a vital role in explaining how calculators support and enrich precalculus content. TCK involves understanding how technology tools are used to enhance the delivery of subject-specific content. In the context of precalculus, graphing calculators serve as powerful tools for visualizing mathematical functions, exploring transformations, and analyzing data sets. By integrating graphing calculators into precalculus instruction, educators provide students with opportunities to engage with mathematical concepts dynamically and interactively, leading to a deeper comprehension of precalculus content (Soler-Costa et al., 2021).

PCK

PCK is essential for developing effective strategies for teaching precalculus concepts using graphing calculators. PCK focuses on the intersection of pedagogy and content knowledge, guiding educators in selecting appropriate instructional methods to facilitate student learning. When integrating graphing calculators in the classroom, teachers employ guided exploration, collaborative problem-solving, and real-world applications to enhance student engagement and promote conceptual understanding. By incorporating formative assessment techniques that leverage the calculators' capabilities, educators provide timely feedback to students and adjust instruction to address individual learning needs effectively (Mahdum, 2015).

Theme 3. Benefits and Challenges

Graphing calculators, like the TI-84 and TI-89 models, offer numerous benefits in mathematics education by enhancing student engagement and understanding through interactive and dynamic learning experiences. These calculators improve engagement by allowing students to explore and experiment with mathematical concepts, leading to increased interest and motivation. However, several challenges must be addressed, including the risk of overdependence on technology, accessibility issues due to cost, and adequate training for teachers and students to maximize the calculators' effectiveness.

Benefits of Graphing Calculators

Graphing calculators, such as the TI-84 and TI-89 models, offer numerous benefits in the mathematics classroom by enhancing student engagement and understanding of complex concepts. One of the primary advantages of graphing calculators is improving student engagement through interactive learning. These calculators enable students to interact dynamically with mathematical concepts, fostering a more profound interest in the subject. Parrot and Leong (2018) emphasize that the interactive nature of graphing calculators encourages students to explore and experiment with mathematical ideas, increasing their motivation to learn. Similarly, research by Mushipe and Ogbonnaya (2019) has shown that graphing calculators increase student interest and enjoyment in learning mathematics as students are empowered to explore mathematical concepts independently.

In addition to enhancing engagement, graphing calculators significantly improve students' understanding of mathematical concepts. One key aspect is their ability to facilitate the visualization of abstract mathematical concepts, such as functions and transformations,

which leads to a more intuitive understanding of mathematical ideas (Kramarenko et al., 2019). The immediate feedback calculators provide also plays a crucial role in deepening students' understanding of mathematical principles. According to Greefrath et al. (2022), instant feedback on calculations helps students correct misconceptions, reinforcing their grasp of mathematical concepts. Furthermore, graphing calculators support problem-solving by enhancing higher-order thinking skills and mathematical reasoning. Mert Uyangör (2019) highlights that these tools assist students in solving complex problems, thereby fostering critical thinking and analytical skills.

Graphing calculators also contribute to real-world applications of mathematical concepts by supporting contextual learning. Randjelović et al. (2020) point out that these calculators help students apply mathematical knowledge to real-world scenarios, demonstrating the relevance of mathematics beyond the classroom. This contextual learning approach enhances students' understanding of mathematics and prepares them to tackle real-life problems using mathematical reasoning.

Challenges Associated with Using Graphing Calculators

Despite the numerous benefits, several challenges are associated with using graphing calculators in the classroom, which educators must address to maximize their effectiveness. One major challenge is the reliance on technology, which can lead to overdependence. Devlin (2021) warns that students may become overly reliant on calculators, potentially hindering their manual arithmetic and algebraic skills. This overdependence can reduce students' problem-solving skills, as excessive use of calculators may lead them to focus more on inputting data than understanding mathematical concepts (Gerofsky & Zebehazy, 2022).

Accessibility issues also pose significant challenges in the use of graphing calculators. The cost and availability of these devices can be a barrier for some students and schools, impacting equitable access to technology tools. González et al. (2022) highlight that the high cost of graphing calculators can prevent some students from accessing these valuable resources, leading to disparities in educational opportunities. Additionally, both teachers and students require adequate training to use calculators effectively. Sepúlveda et al. (2020) emphasize the importance of training to ensure that the benefits of graphing calculators are fully realized, as lack of familiarity can hinder their practical use in the classroom.

Pedagogical challenges are also crucial considerations when integrating graphing calculators into the curriculum. Incorporating these tools requires careful planning and

alignment with learning objectives to enhance student learning. Pielsticker (2024) notes that integrating calculators into the curriculum involves aligning their use with educational goals to maximize their impact on learning outcomes. Furthermore, assessment concerns arise when evaluating students' understanding while using calculators. Hamid et al. (2020) suggest that assessments should evaluate students' conceptual understanding rather than their calculator proficiency, ensuring that students genuinely grasp the underlying mathematical concepts.

Theme 4. Case Study: PreCalculus with TI 84–89 by Meylani (2024)

This section presents the analysis of the book *PreCalculus with TI 84–89* (Meylani, 2024) and its alignment with the TPACK framework. For the book's table of contents, please refer to Appendix 1. The chapters in the book will be summarized as follows:

Chapters in the Book

Chapter 1. TI 84 Basics: Chapter 1 introduces the fundamental operations and features of the TI-84 calculator, which are essential for navigating its functionalities. It begins with instructions on basic operations like turning the calculator on and off, resetting memory, and adjusting screen contrast, ensuring users can start with a straightforward and customizable interface. The chapter covers essential menus such as the Math Menu and Catalog, highlighting the calculator's compliance with the order of operations, i.e. Parentheses, Exponents, Multiplication, Division, Addition, Subtraction (PEMDAS), and its capabilities for editing expressions and accessing previous entries. It also explains the difference between operational and number minus signs, how to store values in variables, and perform conversions between decimals and fractions. The chapter also delves into complex mathematical operations, including roots, powers, operations on complex numbers, and the use of built-in functions relevant to Precalculus (please see Figure 2). The final sections cover advanced topics like radian and degree conversions, unique numbers like Euler's constant and pi, factorial notation, permutations and combinations, sequences, matrices, statistical functions, normal distribution, basic programming, and tools for solving polynomial roots and simultaneous equations.

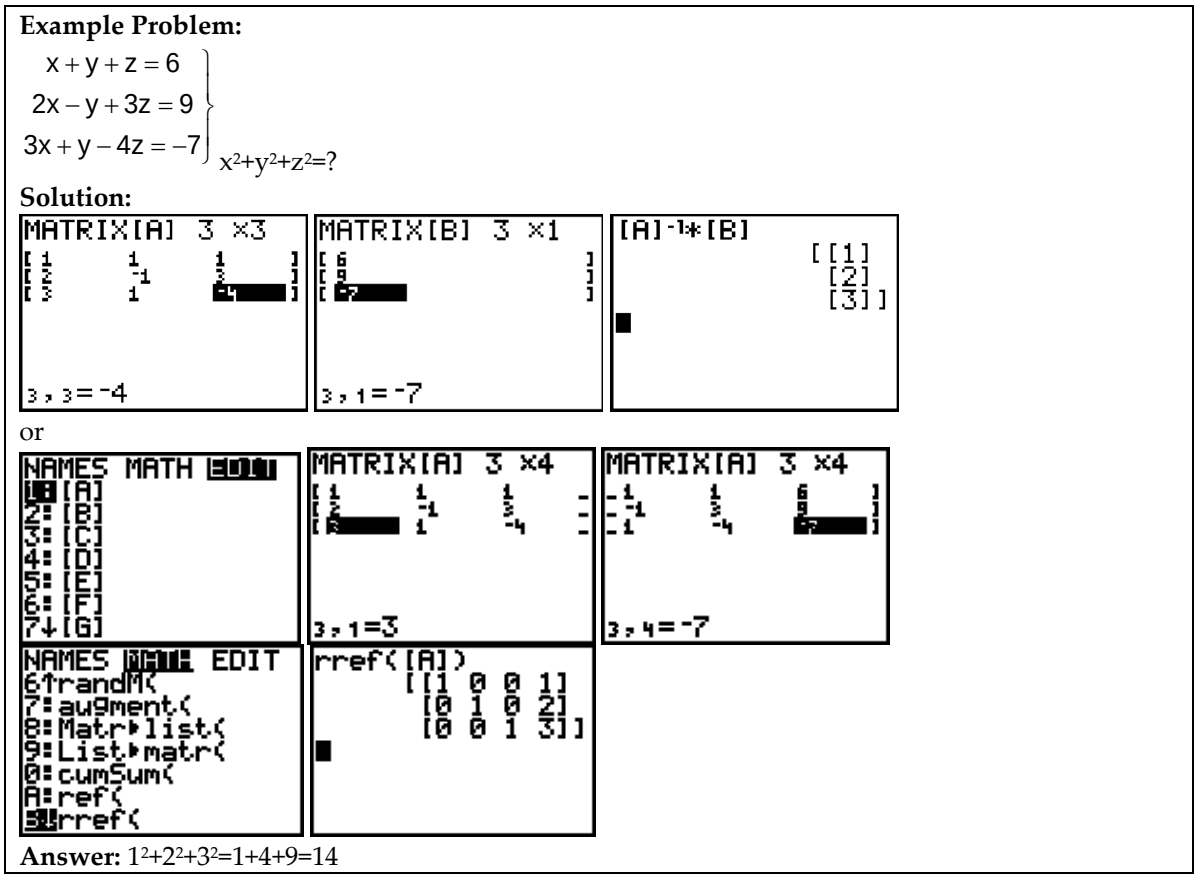
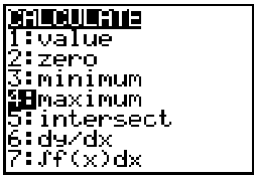


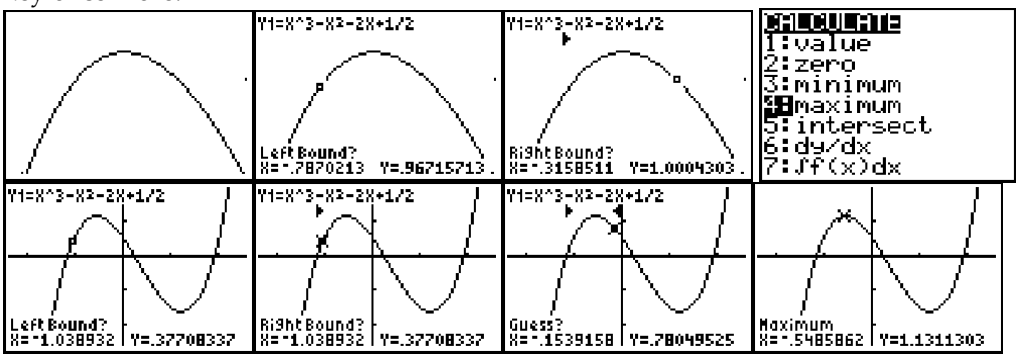
Figure 2. An example for complex mathematical operations and the use of built-in functions relevant to Precalculus with TI.

Chapter 2. TI 84 Graphing Preliminaries: Chapter 2 focuses on the graphing capabilities of the TI-84 calculator, starting with the Y= Editor, where users input equations to be graphed. It explains graph-style icons and the importance of setting the graph viewing window for accurate representation. The chapter guides readers through graphing piecewise functions and understanding the composition of functions, including operations and transformations. It introduces the ZOOM and CALC menus, which provide tools for manipulating graphs and calculating critical points such as intersections, zeroes, maxima, minima and slopes (please see Figure 3 for using TI to find the coordinates of a local maximum point for a polynomial function). Readers also learn about creating tables for graphing parametric equations and plotting polar graphs, essential for visualizing complex mathematical relationships. The chapter concludes with discussions on graphing conic sections, using regression analysis to find equations for lines and parabolas, and summarizing the overall graphing process.

CALC maximum



When **CALC maximum** is selected, the user will be prompted to select the **Left Bound**, and the **Right Bound** of the maximum that is to be found. The left bound must be chosen as a point to the left of the crest of the maximum and the right bound must be chosen as a point to the right of the crest of the maximum. After the **left bound** and the **right bound** are entered correctly, there will be the **guess**ing step which may be passed quickly by pressing the enter key once more.



The left bound and the right bound can also be entered manually as shown in the coming graphs. In this case, the left bound will be the x-coordinate of a point to the left of the maximum and the right bound will be the x-coordinate of a point to the right of the maximum. This option is especially useful when the cursor does not appear on the screen.

Figure 3. Using TI 84 to find the coordinates of a local maximum point for a polynomial function

Chapter 3. Sample TI 84 – 89 Problems: Chapter 3 presents a range of sample problems designed to illustrate the practical applications of the TI-84 calculator in solving various mathematical challenges. It covers polynomial, algebraic, logarithmic, trigonometric, and absolute value equations, demonstrating how the calculator can simplify solving these problems. The chapter includes sections on exponential and logarithmic equations, systems of linear equations, matrices, and determinants, showcasing the calculator's ability to handle complex calculations efficiently. It also addresses trigonometric equations and their inverses, inequalities, and the analysis of maxima and minima. Additionally, the chapter explores domains, ranges, and the properties of functions, including evenness and oddness, with graphs of trigonometric and miscellaneous functions. Further topics include the most significant integer function, parametric and polar graphs, limits, continuity, asymptotes, complex numbers, permutations, combinations, and various miscellaneous calculations, providing a comprehensive overview of the calculator's capabilities. Please see Figure 4 for solving a trigonometric equation graphically with the TI.

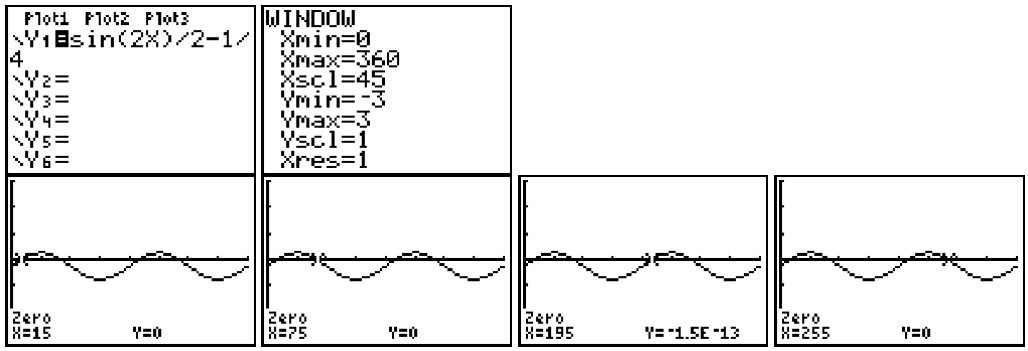
Example Problem:

$$\left.\begin{array}{l}\dfrac{\sin(2\theta)}{2}=\dfrac{1}{4}\\ 0^\circ \le \theta < 360^\circ\end{array}\right\}$$ What is θ?

Solution:

Mode: Degrees

$$\frac{\sin(2\theta)}{2}-\frac{1}{4}=0$$



Answer: 15°,75°,195°,255°

Figure 4: Solving a trigonometric equation graphically with TI 84.

Chapter 4. The TI 89: Chapter 4 introduces the TI-89 calculator, highlighting its advanced features and mode settings. It begins with the Y= Editor and graph style icons, like the TI-84, but is adapted to the TI-89's unique interface. The chapter explains graph viewing window settings and using the ZOOM menu for precise graph manipulation. It details the F5 menu, which offers additional graphing tools, and the creation of tables for analyzing parametric and polar graphs. The chapter emphasizes commonly used functions and provides an overview of the F2 Algebra Menu, showcasing the TI-89's ability to efficiently solve polynomial and non-polynomial equations. It highlights the calculator's advanced capabilities, offering readers a comprehensive guide to leveraging the TI-89 for complex mathematical analysis and problem-solving along with illustrative example problems and solutions. Please see Figure 5 for solving an algebraic system of equations with literals.

Example: SOLVING FOR LITERALS

$$x-y=a$$

$$x^2-y^2=b$$

x=? and y=?

Solution:

Solve($x-y=a$ and $x^2-y^2=b$, {x,y}) ≈ ENTER

$$x=\frac{a^2+b}{2a} \text{ and } y=\frac{-a^2+b}{2a}$$

Figure 5. Using TI 89 to solve an algebraic system of equations with literals.

Analysis of the Book Through the TPACK Framework Lens

The book is analyzed through the lens of the TPACK framework. This involves examining how the text addresses integrating technology, pedagogy, and content knowledge in teaching Precalculus. Here is a detailed analysis based on the TPACK components:

TK

TI 84 Basics: The book provides a dedicated chapter covering the fundamental operations of the TI 84 calculator. This includes turning it on and off, resetting memory, adjusting screen contrast, and using the math menu and catalog for various functions. This section lays the groundwork for understanding the calculator's technological capabilities (Meylani, 2024, pp. 5–6).

Calculator Functions: The book describes in detail the various built-in functions of the TI calculators, such as trigonometric, exponential, logarithmic, and statistical functions. This knowledge is essential for students and teachers to effectively leverage technology (Meylani, 2024, pp. 10–12).

Graphing and Analysis: Instructions on graphing functions, using the graphing preliminaries, and exploring graphing capabilities (e.g., parametric and polar graphing) demonstrate the calculators' technological prowess in visualizing mathematical concepts (Meylani, 2024, pp. 21–35).

CK

Comprehensive Coverage of Precalculus Topics: The book thoroughly covers many Precalculus topics, such as polynomial equations, trigonometric functions, sequences and series, and complex numbers. Each topic is aligned with the relevant functions and operations of the TI calculators (Meylani, 2024, pp. 48–116).

Sample Problems: Numerous examples and exercises are included to provide a robust understanding of Precalculus concepts. These problems illustrate how technology solves complex mathematical equations and analyzes data effectively (Meylani, 2024, pp. 48-118).

PK

Instructional Strategies: Although the book primarily focuses on content and technology, it implicitly supports pedagogical strategies by demonstrating how calculators are used as teaching aids. Solving systems of equations or visualizing functions enhances student understanding and engagement (Meylani, 2024, pp. 64-66).

Learning Progression: The structured presentation of topics, starting from basic calculator operations to advanced applications in solving Precalculus problems, supports a logical progression in learning and caters to different student needs and learning styles (Meylani, 2024, pp. 5-17).

Integration within the TPACK Framework

TPK: The book demonstrates how TI calculators transform traditional teaching methods. Educators create dynamic learning environments that cater to various learning styles by using calculators to explore mathematical concepts interactively (Meylani, 2024, pp. 33-35).

TCK: The book illustrates how the capabilities of the TI calculators are directly applied to Precalculus content. For example, graphing complex functions or solving polynomial equations using the calculator's advanced functions shows the synergy between technology and content knowledge (Meylani, 2024, pp. 35-48).

PCK: While the book focuses more on the technological and content aspects, educators can infer pedagogical strategies for teaching complex concepts effectively. The examples and exercises guide structuring lessons that integrate content knowledge with pedagogical techniques (Meylani, 2024, pp. 64–66).

PreCalculus with TI 84–89 by Meylani (2024) is a valuable resource that aligns well with the TPACK framework. It provides a comprehensive guide to using TI calculators to teach Precalculus, emphasizing integrating technology with content knowledge. While the book excels in technological and content aspects, educators can further enhance pedagogical integration by developing specific instructional strategies that leverage the calculator's capabilities to facilitate student understanding and engagement in Precalculus.

Discussion

Theme 1: Application of TI 84-89 Calculators in Precalculus

The application of TI-84 and TI-89 calculators in precalculus is significant due to these tools' rich technological capabilities, which enhance students' understanding and problem-solving skills. These calculators are equipped with functions that allow for graphing mathematical equations, solving complex equations, analyzing data, and performing statistical calculations, which are crucial for comprehending precalculus concepts (Wu et al., 2020). The graphical interface facilitates the visualization of abstract mathematical concepts such as functions, transformations, and intersections, making them more tangible and aiding

in understanding complex ideas. The programmability of these calculators also supports students' exploration of mathematical concepts through simulations and interactive activities, fostering deeper engagement and comprehension. By enabling such dynamic interaction with mathematical content, the TI-84 and TI-89 calculators are invaluable in supporting the technological knowledge aspect of the TPACK framework, demonstrating how technology can be used effectively to enhance mathematical education.

Theme 2: Integration within the TPACK Framework

Integrating TI-84 and TI-89 calculators within the TPACK framework emphasizes the importance of leveraging technology to enhance pedagogical practices and content delivery in precalculus education. TPK is utilized by incorporating interactive activities that allow students to explore mathematical concepts visually. By guiding students in graphing functions, analyzing data, and solving equations with these calculators, teachers create engaging learning experiences that promote active exploration and more profound understanding (Başer et al., 2016). TCK highlights the role of calculators in visualizing mathematical functions and analyzing data, providing students with dynamic and interactive engagement with precalculus content (Soler-Costa et al., 2021). PCK involves developing strategies for teaching precalculus concepts effectively with graphing calculators, including guided exploration, collaborative problem-solving, and real-world applications. This integration fosters an environment where technology is purposefully aligned with pedagogical and content objectives, enriching the learning experience and supporting student success.

Theme 3: Benefits and Challenges

Graphing calculators, such as the TI-84 and TI-89 models, present numerous benefits by enhancing student engagement and understanding of complex concepts in the mathematics classroom. They facilitate interactive learning, enabling students to engage dynamically with mathematical concepts, which fosters more profound interest and motivation to learn (Mushipe & Ogbonnaya, 2019; Parrot & Leong, 2018). These tools improve students' understanding by helping them visualize abstract mathematical concepts, providing immediate feedback, reinforcing mathematical principles, and promoting problem-solving skills (Greefrath et al., 2022; Kramarenko et al., 2019; Mert Uyangör, 2019). However, challenges include the potential for overdependence on technology, which may hinder manual arithmetic and problem-solving skills (Devlin, 2021; Gerofsky & Zebehazy,

2022). Accessibility issues, such as cost and availability, hinder equitable technology access (González et al., 2022). Additionally, educators must align calculator use with curriculum goals and develop assessments that evaluate students' conceptual understanding rather than mere calculator proficiency (Hamid et al., 2020; Pielsticker, 2024; Sepúlveda et al., 2020).

Theme 4: Case Study: Precalculus with TI 84–89

The book *PreCalculus with TI 84–89* by Meylani (2024) is a comprehensive resource that aligns well with the TPACK framework by integrating technology, pedagogy, and content knowledge in teaching precalculus. It offers detailed technological knowledge by covering the fundamental operations and functions of the TI-84 calculators, such as graphing mathematical functions and analyzing data (Meylani, 2024, pp. 5–35). The content knowledge aspect is addressed by thoroughly covering key precalculus topics and providing numerous sample problems to illustrate how technology can be leveraged to solve complex equations and analyze data (Meylani, 2024, pp. 48–118). Pedagogical knowledge is supported through instructional strategies and learning progressions that demonstrate how calculators can be used as teaching aids to enhance understanding and engagement (Meylani, 2024, pp. 64–66). By illustrating the practical application of TPACK components, the book is a valuable guide for educators seeking to integrate graphing calculators into their precalculus curriculum, highlighting how technology can be leveraged to facilitate student understanding and engagement.

Suggestions for Policy and Practice

To effectively integrate TI 84 and TI 89 graphing calculators into Precalculus instruction using the TPACK framework, educational policymakers, and practitioners should consider several key strategies. First, it is crucial to provide comprehensive professional development programs for educators that focus on the intersection of technology, pedagogy, and content knowledge. These programs should equip teachers with the necessary skills to integrate graphing calculators into their curriculum, emphasizing hands-on training and collaborative learning opportunities. Additionally, schools should ensure equitable access to graphing calculators for all students, possibly through funding initiatives or partnerships with technology providers like Texas Instruments. Policymakers could also consider incorporating technology literacy and calculator skills into the mathematics curriculum to prepare students for the digital demands of modern education and industry. Furthermore, educators should be encouraged to adopt innovative assessment

methods that evaluate students' conceptual understanding rather than mere calculator proficiency, thereby aligning assessments with the integrated learning objectives of the TPACK framework. By addressing these areas, educational institutions can optimize graphing calculators to enhance student learning outcomes in Precalculus and beyond.

Research Gaps and Future Research Directions

While integrating TI 84 and TI 89 graphing calculators in Precalculus instruction has shown promise, several research gaps warrant further exploration. One significant gap is the lack of empirical studies assessing the long-term impact of calculator use on student learning outcomes across diverse educational settings. Future research should focus on longitudinal studies that track student performance and engagement over time, providing insights into how sustained calculator use affects mathematical proficiency and interest in STEM fields.

Additionally, there is a need for more research on the effectiveness of specific pedagogical strategies within the TPACK framework when using graphing calculators. While current studies emphasize the benefits of interactive learning and visualization, there is limited evidence on how different instructional approaches, such as collaborative learning or inquiry-based methods, interact with calculator usage to enhance student understanding. Future research should investigate these pedagogical strategies in depth, exploring their impact on various student populations and learning environments.

Another area that requires further investigation is the potential barriers to equitable access to graphing calculators and how these barriers affect student achievement. Research should examine the socioeconomic and institutional factors that influence access to technology and identify strategies to mitigate these challenges, ensuring that all students can benefit from technological advancements in mathematics education.

Furthermore, exploring integration of other emerging technologies, such as mobile apps or online platforms, alongside graphing calculators could provide valuable insights into creating comprehensive digital learning environments. Future research should consider the synergistic effects of combining multiple technologies within the TPACK framework, assessing how they collectively enhance teaching practices and student outcomes.

Lastly, research should address the professional development needs of educators, focusing on how training programs can effectively prepare teachers to integrate technology into their instruction. Studies should explore the components of successful professional

development programs and their impact on teachers' confidence and competence in using graphing calculators in the classroom.

By addressing these research gaps, future studies will contribute a more comprehensive understanding of how graphing calculators and the TPACK framework can be leveraged to improve Precalculus instruction and mathematics education.

Conclusion

Summary of Key Insights

This study explored the integration of TI 84 and TI 89 graphing calculators in Precalculus instruction through the TPACK framework. The findings confirm that these calculators serve as valuable technological tools that enhance students' engagement, conceptual understanding, and problem-solving abilities in mathematics. The study revisited the research questions, demonstrating that integrating TK, PK, CK leads to more interactive and effective learning experiences (Mishra & Koehler, 2006).

The thematic analysis revealed four key themes:

- *Application of TI 84 and TI 89 Calculators in Precalculus:* These calculators facilitate the visualization of abstract mathematical concepts, making problem-solving more interactive and accessible (Wu et al., 2020).
- *Integration within the TPACK Framework:* The interplay between technology, pedagogy, and content knowledge ensures that graphing calculators enhance instructional practices effectively (Costa et al., 2021).
- *Benefits and Challenges:* While graphing calculators improve student engagement and understanding, concerns such as over-reliance on technology and accessibility issues must be addressed (González et al., 2022).
- *Case Study of "Pre-Calculus with TI 84-89":* The book effectively demonstrates how TI calculators align with the TPACK framework, providing structured guidance for educators and students.

Implications for Practitioners

The study's findings offer several key implications for educators, policymakers, and curriculum developers:

- *Strategic Technology Integration:* Teachers should intentionally integrate TI 84 and TI 89 calculators into lesson plans rather than using them as mere computational tools.

Incorporating them into problem-solving exercises, visual demonstrations, and interactive learning activities will maximize their effectiveness (Rodríguez, 2019).

- *Professional Development and Teacher Training:* Many teachers lack formal training in using graphing calculators for instruction (Othman & Maat, 2020). Professional development programs should focus on building TPACK competencies to ensure educators can seamlessly integrate technology into pedagogy.
- *Equitable Access to Technology:* Cost and availability remain major barriers to calculator use in classrooms (González et al., 2022). Schools and policymakers should explore funding initiatives, including subsidized calculator programs or digital alternatives to ensure all students have access to these learning tools.
- *Assessment and Evaluation:* Current assessment methods should go beyond procedural fluency to evaluate conceptual understanding and higher-order thinking skills when using graphing calculators. Educators can redesign assessments that measure students' ability to interpret graphs, analyze functions, and apply mathematical reasoning effectively (Parrot & Eu, 2018).
- *Future Research on Longitudinal Impacts:* Further studies should examine long-term student outcomes related to graphing calculator integration, particularly in relation to STEM career readiness and higher-level mathematics performance.

Limitations

While the study provides valuable insights into integrating TI 84 and TI 89 graphing calculators within the TPACK framework, several limitations must be acknowledged. Firstly, the study relies on a qualitative theoretical approach, which may not capture the full range of practical challenges and outcomes associated with graphing calculators in diverse educational settings. While helpful in developing theoretical understanding, the reliance on literature synthesis and conceptual analysis may limit the generalizability of findings to specific classroom contexts. Additionally, the study does not include empirical data from classroom observations or student assessments, which could provide more concrete evidence of the impact of graphing calculators on student learning outcomes. Furthermore, focusing on the TI 84 and TI 89 models may not account for the varying functionalities of other graphing calculators or technological tools educators might use. Future research should consider these limitations by incorporating mixed methods approaches, empirical data

collection, and comparisons with other educational technologies to provide a more comprehensive understanding of the role of graphing calculators in mathematics education.

Final Thoughts

By bridging technology, pedagogy, and content knowledge, this study reaffirms that TI 84 and TI 89 calculators are more than computational devices—they serve as powerful instructional tools that enhance student learning in Precalculus. However, their effective use requires careful planning, training, and equitable implementation. Educators and policymakers should leverage these findings to develop structured guidelines for incorporating graphing calculators into mathematics education, ensuring technology-enhanced learning environments that benefit all students.

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Due to the scope and method of the study, ethics committee permission was not required.

Author Contribution Statement

Rusen MEYLANİ: *Conceptualization, design, literature review, methodology, data collection, data analysis, interpretation, writing, and editing.*

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Appendix.

Table of Contents of the Book Entitled *PreCalculus with TI 84–89*.

Table of Contents