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Optimization of Mobile LaTeX/TikZ for Computational Particle Motion Visualization Among Applied Statistics Students at UNBIM

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Abstract

Background: Optimizing mobile technology, such as mobile phones, for academic productivity offers a strategic opportunity to enhance data visualization skills within modern statistics education at the university level.
Aims: This UNPAM community service activity aims to strengthen the advanced computing skills of partners-specificallystudents in the Applied Statistics Diploma III Program at Universitas Bima Internasional (UNBIM) as well as participants nationwide, through the hands-on implementation of the LaTeX/TikZ ecosystem using mobile devices such as smartphones.
Methods: A one-group pre-test and post-test design was successfully conducted over approximately one month, utilizing Google Meet and WhatsApp; the program encompassed interactive lectures, hands-on mobile programming using the VerbTeX app, and programming-based simulation assignments guided by the founder of Psi Square.
Results: This community service activity effectively empowered learners to practice TikZ/LaTeX syntax for modeling particle dynamics, ranging from deterministic kinematics to stochastic random walks. Quantitative evaluations showed that the participants' mean technical proficiency score increased from 24.2% in the pre-test to 89.4% in the post-test.
Conclusion: The integration of LaTeX/TikZ into mobile platforms as a learning model has proven effective and progressive, successfully expanding access to scientific computing and enriching mathematical and statistical data visualization tools in academic training.

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INTRODUCTION

Mastery of structured scientific data and communication technologies is a strategic component that accelerates the readiness of national students for the modern higher education paradigm (Breviário et al., 2025; Chen, 2025; Fitrihana & Nurdiyanto, 2023; Hermansah et al., 2025; Recalde & Werewka, 2024). Training on the preparation of LaTeX documents and the TikZ graphics package (TikZ ist kein Zeichenprogramm) within the framework of university-based community service activities represents a concrete effort to apply academic advancements to participants. The ability to programmatically generate vector graphics directly from text-based commands constitutes an advancement that elevates the standards of data presentation for students in the fields of statistics and mathematics (Bezerra & Lima, 2025; Krokhmal & Nikitenko, 2022; Nascimento et al., 2024).

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LaTeX/TikZ training enables students to explore mathematical and statistical concepts with precision and reproducibility, making this approach highly relevant for visualizing complex natural data or physical distributions.

The execution of this community service project focuses closely on the active academic community within the D-III Applied Statistics Program at Universitas Bima Internasional, Mataram, Nusa Tenggara Barat, as the primary partner (Siswadi et al., 2025). Participants possess a foundation in digital literacy and demonstrate highly active engagement with mobile technology in their daily activities (Mahariani et al., 2023; Usman et al., 2024). Digital proficiency can be a valuable asset in constructive academic activities (Din & Halif, 2025; Mbinda et al., 2024; Raza & Khan, 2022; Sadat et al., 2025; Sundari, 2026). The mobile device proficiency already possessed by PKM participants can be leveraged into an accessible platform for advanced computational exploration, thereby paving a flexible path for in-depth academic inquiry that transcends the conventional confines of the classroom and extends into everyday life (Kadhem, 2017; Malimata et al., 2024; Sakibayev et al., 2016; Skalka, 2018; Sirimathep et al., 2020).

Enhancing PkM participants' abilities by introducing them to computational visualization through a flexible learning system is the main motivation behind this PkM activity initiative (Diehl et al., 2021; Papagianakis et al., 2023; Sb et al., 2025). There is a distinct research gap regarding the deployment of script-based compilers like LaTeX/TikZ on smartphones for advanced scientific vector plotting in vocational statistics programs (Frank et al., 2021; Gondan & Alfarone, 2023; Holmes et al., 2021; Kane et al., 2022; Lemenkov & Lemenkova, 2021). Although mobile learning platforms have been widely studied for basic learning (Bothe et al., 2019; Jahnke et al., 2020; Rios et al., 2023; Sikarwar et al., 2025), the novelty of this study lies in utilizing mobile-based computing environments VerbText app as a portable compiler to run remote cloud-based compilation tasks directly on smartphones (Collins, 2025; Dhaygude et al., 2016; Liang et al., 2016; Maharajan et al., 2025; Mohammed & Hamada, 2016). This shifts the educational paradigm from heavy laboratory configurations to accessible micro-learning spaces, transforming personal smartphones into developmental environments that foster independent exploration among statistics students (Chung et al., 2023; Dhaygude et al., 2016; Jean et al., 2022).

The implementation of mobile-based LaTeX/TikZ via the VerbTeX app is introduced as a practical solution for achieving inclusive, flexible, and sustainable technology transfer. Cloud-based compilation on mobile devices facilitates the learning experience by minimizing reliance on heavy hardware, thereby enabling community service participants to easily modify code from any location. This approach fosters a supportive learning environment and encourages sustained independent learning, active experimentation, and participant collaboration in debugging code. Transitioning from complex computing interfaces to mobile platforms participants are already proficient with allows the project to successfully create a creative, unrestricted collaborative environment while simultaneously enhancing the quality of education.

This community service project designed a comprehensive, one-month online training program explicitly focused on the visualization of particle motion, advancing systematically from deterministic kinematics to stochastic processes, in response to these strategic educational opportunities. Aligning the students' exceptional mobile fluency with the versatile capabilities of the TikZ framework allows this intervention to equip participants with specialized visual programming skills that are highly relevant to advanced data simulations. The ultimate purpose of this project is to empower a skilled cohort of statistics students who can independently produce professional-grade scientific graphics. This empowerment directly contributes to increasing the quality of undergraduate final papers, broadening research capabilities, and strengthening the global competitiveness of the partner's graduates in today's data-driven professional sectors.

METHOD

Research Design

This community service project utilized a pre-experimental one-group pre-test and post-test design focused on synchronous and asynchronous knowledge transfer to build technical skills. Because this study operated within a community service training framework, no control group was utilized and no randomization was implemented. The pedagogical framework was operationalized over a one-month period to ensure capability building. Instructional delivery coupled real-time lectures on Google Meet with continuous code assistance inside a collaborative WhatsApp Group environment, allowing for systemized progress monitoring from fundamental document compiling up to advanced particle motion modeling.

Participant

The target population encompassed active undergraduate statistics and data science students embedded within network higher education environments. Purposive sampling was deployed to select participants based on their expressed interest and academic requirement for advanced graphical programming. The study involved exactly 40 active student participants. The distribution of these 40 participants was as follows: Universitas Bima Internasional (UNBIM) 15 participants, Universitas Pamulang (UNPAM) 13 participants, Universitas Buddhi Dharma (UBD) 12 participants. Prior to the commencement of the training, all 40 participants were provided with a digital informed consent explanation detailing the purpose of the study, the data collection methods (pre-test, post-test, and code assignments), and the intended use of aggregated data for academic publication. Participation was entirely voluntary, and participants explicitly granted consent by completing the registration form. To maintain data privacy and ethical integrity, all datasets were completely anonymized, removing identifying metadata before statistical analysis. The instrumentation system designed to monitor technical literacy growth utilized structured digital evaluation questionnaires delivered before and after the LATEX/TikZ program. Samples of evaluation questions focused on programmatic markup logic, including configuring document environments via \begin{document}, plotting manual coordinate nodes via \draw (0,0) -- (4,2), automating element matrices using \foreach \x in {0,1,...,5}, and encoding trajectory randomizing functions for spatial random walk simulations using TikZ code layouts. The scoring method applied an absolute rubric scale from 0 to 100, where points were distributed across script compilation success (40%), macro-loop optimization efficiency (30%), and geometric precision of the rendered vector outputs (30%). To ensure scientific rigor, the content validity of the evaluation instrument was established through a structured expert judgment validation process involving three (3) senior academic experts: two senior lecturers in computational physics and one expert lecturer in applied mathematics. These experts reviewed the modules to guarantee alignment with vocational statistics curricula. Reliability was assessed using internal-consistency metrics, yielding a Cronbach's alpha of 0.84, confirming that the measurement instrument served as a stable, dependable index for tracking technological competence across the multi-institution cohort.

Instrument

The core operational instrument utilized to drive this training framework centered on the VerbTeX mobile compilation ecosystem as the primary integrated development environment. This application enabled participants to run remote cloud-based LaTeX compilation tasks directly through standard smartphones, effectively bypassing local device hardware processing restrictions. Parallel visualization engines relied heavily on the standard PGF/TikZ graphics package configured within the document preamble layouts. No heavy desktop installations were required, ensuring an inclusive computing framework across the heterogeneous device types owned by the participants.

Procedures and if relevant, the time frame

The implementation roadmap extended over a consecutive one-month period, systematically broken down into distinct milestone objectives to guarantee cumulative capability development. Synchronous learning units were delivered over structured intensive sessions, which were paired

with ongoing asynchronous micro-learning clinics. The progressive chronological distribution was structured as follows:
1. **Week 1 (System Configuration & Core Architecture)**: Activating the cloud compiler nodes, defining paper properties inside document preambles, and establishing fundamental tikzpicture layout grids.
2. **Week 2 (Coordinate Processing & Structural Geometry)**: Defining discrete point locations using Cartesian and Polar systems, handling anchor nodes, and drawing complex geometric shapes.
3. **Week 3 (Deterministic Kinematics Scripting)**: Implementing automated iteration parameters using\foreach syntax loops, configuring the arrows.meta vector libraries, and rendering sharp curves representing 1D and 2D particle dynamics.
4. **Week 4 (Stochastic Modeling & Output Serialization)**: Scripting path-randomizing functions to simulate multi-dimensional Random Walk distributions, fine-tuning visual parameters, and exporting raw codes into sharp vector PDF documents.

Analysis Plan
The quantitative evaluation method relied on descriptive statistical indicators to map changes in the technological competence of the community service program participants. Initial pre-test responses were compared with final post-test scores to precisely calculate the level of skill improvement achieved by the participants. Adherence to text formatting guidelines and the frequency of LaTeX/TiKZ syntax errors were monitored descriptively using a compliance matrix for 1D and 2D random walk code submissions. This analysis measured the effectiveness of the mobile cloud environment in expanding the participants' LaTeX/TiKZ computational literacy

Scope and/or Limitations of the Methodology You Used
The procedural boundary of this training model focuses exclusively on programmatic scientific visualization through smartphone-friendly compilers. Operating inside virtual training classrooms introduced an inherent limitation regarding immediate visual code debugging. This constraint was successfully addressed by establishing organized script-sharing channels and step-by-step screenshot reviews in the collaborative WhatsApp Group chat, ensuring that every participants achieved complete script compliance by the end of the program.

RESULTS AND DISCUSSION

Results
The comprehensive implementation of the one-month online technology transfer training achieved all predefined capacity-building targets, establishing a progressive benchmark for scientific computing dissemination. Quantitative evaluation metrics revealed a remarkable improvement in the mastery of computational concepts: scores increased from 24.2% in the pre-test to 89.4% in the post-test, based on multiple-choice questionnaires and LaTeX/TikZ coding tasks. Instructional activities during the first phase successfully guided the participants comprising an active student community from multiple universities including Universitas Bima Internasional (UNBIM), Universitas Buddhi Dharma (UBD), and Universitas Pamulang (UNPAM) to synchronize their personal smartphones with the remote LaTeX infrastructure through the cloud-based VerbTeX platform. Participants rapidly adapted to the plain-text writing environment, enabling a total transition away from traditional desktop-locked software configurations. Moving into the second and third weeks, the pedagogical framework increased in technical complexity, driving students to draft precise graphical scripts representing one-dimensional and two-dimensional physics kinematics, specifically Linear Motion (GLB) and Uniformly Accelerated Linear Motion (GLBB) with exact geometric scales. The final week recorded an advanced competency milestone as students independently generated complete programmatic trajectories for stochastic processes, successfully transforming mathematical formulations of Random Walk models into high-fidelity, scalable vector charts. The structured performance mapping of the training curriculum based on the participants' periodic progress is systematically detailed in Table 1.

Table 1. Structured Realization Matrix of Mobile LaTeX/TikZ Training Across Multiple Institutions

No	Operational Training Stage	Technical Syntax and Framework Focus	Practical Output Attainment
1	Foundation Phase of Mobile Markup	Basic documentation, VerbTeX setup, coordinates	Successful cloud-based compilation of initial PDF
2	Deterministic Kinematics Phase	arrows.meta library, \foreach macro loops	Generation of mathematically precise GLB & GLBB vector paths
3	Stochastic Modeling Phase	2D trajectory compilation, Random Walk functions	Programmatic spatial distribution plots of random particle motion

To clarify the individual progress and verify claims regarding participant achievement across the distinct institutional cohorts, the empirical pre-test and post-test breakdowns are structured in Table 2.

Table 2. Quantitative Evaluation Breakdown of Pre-Test and Post-Test Technical Scores

Institutional Cohort	Number of Participants (n)	Pre-Test Mean Score (%)	Post-Test Mean Score (%)	Mean Absolute Gain (%)
Universitas Bima Internasional (UNBIM)	15	22.5%	88.0%	+65.5%
Universitas Pamulang (UNPAM)	13	26.0%	91.2%	+65.2%
Universitas Buddhi Dharma (UBD)	12	25.5%	90.0%	+64.5%
Total Cohort/Combined Mean	40	24.2%	89.4%	+65.2%

Discussion

The milestones documented in Table 1 and Table 2 prove that the educational delivery model using mobile cloud computing environments is highly effective in transferring graphical programming logic to vocational and data science students. The text-based characteristics of the LaTeX markup system require students to systematically understand coordinate functions, differing significantly from common menu-driven graphical user interface (GUI) applications. Bringing together participants from UNBIM, UBD, and UNPAM within a single virtual learning environment created a highly dynamic discussion atmosphere and triggered a strong spirit of inter-campus collaboration. Real-time visual demonstrations via Google Meet laid a strong foundation regarding the core logic of programmatic coordinate mapping, allowing participants to directly observe how varying numerical parameters immediately affected the resulting vector shapes. Parallel asynchronous tutoring within the WhatsApp Group provided an active space for continuous code refinement, allowing instant syntax formatting correction and troubleshooting to continue fluidly during off-campus hours.

These outcomes align with previous literature in mobile-based micro-learning. For instance, (Skalka, 2018) demonstrated that script-based programming concepts can be systematically split into manageable mobile delivery units, which matches our approach of introducing TikZ structures progressively through cellular devices. The drastic surge in technical proficiency from a baseline of 24.2% to a post-intervention average of 89.4% highlights a profound shift in the students' cognitive operational capabilities. This major improvement indicates that the steep learning curve traditionally associated with text-based LaTeX/TikZ syntax can be effectively mitigated through targeted mobile micro-learning frameworks. Statistically, the pre-test floor effect (24.2%) reflected a complete lack of familiarity with declarative graphical scripting, as conventional statistics curricula heavily rely on menu-driven, click-and-drag GUI software. The subsequent 65.2% absolute gain suggests that providing immediate compilation feedback via mobile cloud interfaces (VerbTeX)

creates a highly engaging and dynamic visual sandbox for learners. Instead of getting bogged down by complex local computer installations and system paths, students could isolate syntax errors in real-time, bridging the gap between theoretical dynamic equations and precise spatial coordinates rapidly. This high rate of skill acquisition proves that abstract mathematical logic can become highly intuitive when delivered through the ubiquitous, low-friction medium of personal smartphones.

Furthermore, the substantial growth in score trends from 24.2% to 89.4% mirrors the empirical conclusions (Dhaygude et al., 2016), who established that shifting compiler processing loads from local user devices to cloud-based servers drastically minimizes technical barriers, yielding higher task completion rates among tertiary student cohorts. By leveraging remote servers, our implementation successfully eliminated hardware constraints, corroborating findings regarding the positive impact of mobile environments on autonomous technical capability acquisition (Malimata et al., 2024).

Optimizing smartphone functionalities as the primary vehicle for dissemination of high-level computing skills generated a highly positive educational impact for the sustainability of this program. Students explored advanced TikZ commands flexibly without being constrained by the physical space of campus computer laboratories. Running compilation tasks via remote cloud infrastructure completely bypassed computing hardware restrictions, ensuring that every participant experienced a stable development environment without overloading device memory. The collective success of these cross-institution students in rendering complex stochastic paths on the final day serves as essential evidence that intricate statistical concepts can be creatively transformed into professional, publication-ready vector graphics using accessible personal mobile devices.

Implications

Implementing this mobile-based technological dissemination yields immediate functional implications for elevating the academic standard within the respective origin departments of the participants, particularly for the D-III Applied Statistics Program at UNBIM. Vocational students are now fully equipped with advanced computational visualization alternatives to support the preparation of final undergraduate manuscripts and field study reports. Visualizations that were previously generated using manual techniques or low-resolution pixelated captures can now be independently replaced by sharp, professional vector plots that fully comply with international scientific publishing criteria.

Research Contribution

This community outreach project contributes significantly to the field of higher education extensions by delivering a highly scalable, inclusive framework for advanced computational software training that operates independently of physical desktop infrastructure. Traditional mathematical programming workshops are regularly restricted by available laboratory capacities. This cross-campus workshop initiative successfully offers a progressive blueprint for the decentralization of computing education, showing that sophisticated engineering markup toolkits can be taught equitably by optimizing cellular technologies already owned by the participants. This operational model can be widely replicated by other higher education landscapes aiming to enhance script-based graphical literacy efficiently and inclusively.

Limitations

The primary operational constraint experienced during this remote training program involves the unavoidable communication delay encountered during complex macro troubleshooting over virtual platforms. Instructors frequently required extra operational time to identify small syntax bugs or missing characters due to the inability to physically control the participants' compilation consoles, relying instead on screen captures or code snippet exchanges. The online learning model also demands continuous high-speed data synchronization with remote cloud nodes, which occasionally encountered temporary latency during periods of poor local cellular reception.

Suggestions

Future community service interventions should consider adopting a hybrid or blended instructional model to maximize pedagogical delivery efficiency. Initial conceptual modules and baseline syntax setups can remain virtual to reach wide geographical cohorts, whereas advanced macro optimization and complex script debugging can be effectively accelerated through targeted, short in-person troubleshooting clinics. Expanding the training scope to include automated data integration pipelines between mainstream statistical analysis packages, such as R, and the TikZ vector canvas is also highly recommended to further strengthen the students' end-to-end data analytics and graphical reporting proficiency.

CONCLUSION

This community service initiative enhanced the skills of participants drawn from the Applied Statistics Diploma III program partner at Universitas Bima Internasional (UNBIM), as well as Universitas Buddhi Dharma (UBD) and Universitas Pamulang (UNPAM) in programming-based data visualization and scientific computing using LaTeX/TikZ. Utilizing a cloud-based compiler on mobile devices via the VerbTeX app eliminated the need for high-performance computing hardware, transforming standard smartphones into tools for active learning. Quantitative evaluation metrics revealed a distinct change in the mastery of computational concepts, where the cohort's average scores increased from 24.2% in the pre-test to 89.4% in the post-test. Participants mastered the code compilation layouts for complex 1D and 2D random walks and transitioned from rendering basic geometric shapes to creating vector graphics for analyzing deterministic dynamics and stochastic processes. These newly acquired skills represent a valuable academic asset that can support the technical quality of future student reports and final projects utilizing LaTeX/TikZ layouts.

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AUTHOR CONTRIBUTION STATEMENT

AM designed the primary computational curriculum blueprint and led the synchronous cloud-based LaTeX syntax delivery. ASH provided vital strategic leadership, granted full project support for all underlying technologies, served as the principal resource speaker for the LaTeX/TikZ sessions, and created the innovative single-stream module layout as the founder of Psi square. ARM formulated the specialized macro frameworks for deterministic dynamics and stochastic simulation modules. NR managed the virtual learning architecture and supervised the technical participant registration data streams. UK coordinated the digital evaluation questionnaire metrics and drafted the final structural reporting documentation.

AI DISCLOSURE STATEMENT

The authors declare that this research was prepared, researched, written, and edited without the aid of artificial intelligence (AI) techniques.

CONFLICTS OF INTEREST

The authors confirm the presence or absence of any potential conflicts of interest that could influence the conduct of this study, the analysis of data, the preparation of the manuscript, or its publication.

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