JTAM (Jurnal Teori dan Aplikasi Matematika)
http://journal.ummat.ac.id/index.php/jtam
p-ISSN 2597-7512 | e-ISSN 2614-1175
Vol. 10, No. 3, July 2026, pp. 1012-1026

Analysis of Prospective Teachers' Self-Training Needs Regarding Mathematical Software Adaptation

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Article History:
Received : 26-12-2025
Revised : 10-03-2026
Accepted : 14-03-2026
Online : 01-07-2026

Keywords:
Prospective Teachers;
Mathematical Software;
Self-Regulated Learning;
Digital Native Paradox.

ABSTRACT

In the modern educational landscape, the integration of technology into mathematics education is crucial, and prospective teachers are expected to be not only passive users but also adaptive developers of digital content. Despite being labeled as the "digital generation," a paradox has emerged where general technological proficiency does not equate to competence in specialized mathematics software. This study addresses the self-paced training needs of prospective mathematics teachers at Universitas PGRI Wiranegara, aiming to improve their ability to adapt learning software effectively. Using a qualitative descriptive approach, data were collected through questionnaires and in-depth interviews with final-year students, with the instruments validated through expert assessment and data triangulation to ensure reliability and accuracy. The study revealed a significant gap in technological proficiency: 88% of respondent demonstrated proficiency in basic visualization techniques, but only 4% mastered advanced features such as scripting. Analysis of self-paced learning patterns highlighted issues such as fragmented learning, reactive learning, and high cognitive load, underscoring the urgent need for a structured, project-based self-paced training roadmap. This roadmap will guide prospective teachers from understanding mathematical abstractions to effectively implementing digital functions, empowering them to become competent digital content developers and increasing the effectiveness of their teaching in technologically integrated classrooms.

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https://doi.org/10.31764/jtam.v10i3.37325
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A. INTRODUCTION

Today, the digitalization of global education places technology integration as a key pillar in transforming mathematics learning worldwide. This digitalization process goes beyond simply introducing modern devices into the classroom; it also revolutionizes the way we view and approach teaching (Adipat, 2021). In line with 21st-century educational standards, mastery of mathematics software is no longer merely an additional skill but has become an essential competency for educators in this modern era (Özçakır et al., 2020; Velten et al., 2024). The ability to use this technology is crucial for visualizing abstract concepts that are often difficult to grasp through verbal explanations or writing on a whiteboard alone. Technology enables educators to create simulations and animations that clarify these concepts and improve students' numeracy literacy in a more interactive and engaging way.

With the integration of technology, the learning process can be adapted to the needs of the times, ensuring that students not only understand mathematics theoretically but also can apply it in real-world contexts relevant to the developments of Industry 4.0. In this context, the effectiveness of mathematics teaching depends heavily on teachers' ability to integrate pedagogical content with dynamic and innovative digital tools (Viberg et al., 2023). Teachers are required to continuously adapt and innovate to optimally utilize technology, making learning more effective and engaging. In this way, students acquire not only knowledge but also the skills necessary to compete in an increasingly complex and high-tech workplace (Oner, 2020; Yin, 2021).

The integration of technology into mathematics learning requires prospective teachers to be proficient in operating dynamic software. In Indonesia, the challenge of digital literacy remains very real. Despite high penetration of digital devices, prospective teachers' ability to adapt technology for specific pedagogical purposes remains low (Amelia, 2025; Nazaretsky, 2022). This reinforces the "Digital Native Paradox" phenomenon, where students who are considered technologically fluent are actually only proficient in using technology for entertainment, but struggle with complex mathematical software like GeoGebra or Desmos.

While crucial, the transition to technology-based learning faces various challenges, such as low levels of self-adaptation among prospective teachers. These challenges include the ever-evolving complexity of software interfaces, limited time in formal curricula to practice using each type of application, and technology anxiety that hinders innovation (Frohlich et al., 2020; Yani, 2025). As a result, prospective teachers often become trapped in superficial software use without exploring advanced features crucial for solving complex mathematical problems, thus stagnation in their professional development.

In the past five years, several studies have explored the use of technology in mathematics learning, including the use of GeoGebra in geometric visualization by Ahmad & Nasution (2020), the effectiveness of Desmos in learning functions by Li & Wang (2022), the role of MATLAB in advanced calculus by Smith (2022), the integration of technology into the mathematics curriculum by Pratama et al. (2023), the challenges of digital literacy for prospective teachers by García-Sampedro et al. (2021), and the influence of technical training on teacher self-confidence by Hidayat & Putri (2022). However, these studies often focus too much on student learning outcomes or are technical in nature, neglecting the process of teacher self-learning. Furthermore, they lack concrete solutions regarding self-training mechanisms specific to the individual needs of prospective teachers.

This research introduces a novel approach by delving deeply into the "how" of prospective teachers' self-training designs, focusing on self-regulated learning in the context of adapting mathematical software (Abror, 2022; Adhya & Panda, 2026). Moving beyond traditional methods that emphasize centralized training or formal workshops, the primary aim is for prospective teachers to develop effective, independent learning strategies tailored to their individual needs, thereby enhancing their proficiency in utilizing the software (Sudatha & Agustini, 2026). A critical gap identified is the disconnect between the widespread availability of mathematics software and the prospective teachers' ability to learn and integrate it autonomously into their teaching practices. Despite a plethora of software with diverse formats and features designed to aid the learning process, prospective teachers often struggle to incorporate these tools effectively (Hsu, 2020). Prospective teachers face several challenges when integrating mathematics software into their teaching methods, including lack of familiarity with the software's full capabilities, technical difficulties, time constraints, and limited resources (Widana, 2020). To address these challenges and enhance self-regulated learning skills, the research proposes several strategies: personalized learning plans, peer collaboration, incremental learning, and improved access to resources. By exploring self-regulated learning in the context of mathematical software, this research aims to bridge the gap between software availability and effective utilization by prospective teachers. Through identifying barriers and proposing practical solutions, the study seeks to empower teachers to develop robust independent learning strategies, ultimately enhancing their teaching practices and student engagement.

This study utilizes two main theoretical frameworks, namely Technological Pedagogical Content Knowledge (TPACK) and Self-Regulated Learning (SRL), to understand and analyze the role of technology and self-regulated learning in mathematics education. TPACK is used to map where knowledge about software intersects with mathematics content and pedagogy, helping educators effectively integrate technology, content, and teaching methods, with a focus on the integration of technology, mathematics content, and pedagogical strategies (Amelia, 2025; Shinta & Agoestanto, 2025). Meanwhile, SRL is used to analyze how individuals organize, integrate, and broadcast their self-regulated learning processes, which involve self-regulation, process monitoring, and self-evaluation (Lämsä et al., 2026). This study also highlights the concepts of technology adaptation, which refers to the process of assimilating software features into cognitive structures and conducting teaching practices, self-training, which describes the gap between actual competencies and expected standards, and dynamic mathematics software, which requires continuous updating. By using the TPACK and SRL frameworks, this study aims to improve understanding of the use of technology in mathematics education and improve students' self-regulation abilities in learning.

The digital native generation, born and raised in the digital technology era, faces a digital paradox where, despite being familiar with technology from an early age, many prospective teachers struggle to utilize mathematics software for professional educational purposes. This phenomenon highlights the importance of tailored training (Ramadhani et al., 2022). Identifying the needs of prospective teachers for self-directed training is crucial for improving the quality of mathematics teaching in the future, as self-directed training allows them to learn at their own pace and style (Khaidir et al., 2026). This study aims to contribute to the professional development of prospective teachers by emphasizing the importance of self-directed learning and technology adaptation in mathematics education. The results are expected to be a valuable reference for educational institutions and policymakers in designing responsive and effective training programs. Such programs should accommodate varying levels of comfort and ability in using technology, so that prospective teachers become more confident and competent in teaching mathematics with software. Ultimately, emphasizing self-directed learning and technology adaptation is expected to prepare prospective teachers to face the challenges of teaching in the digital era, improve the quality of mathematics teaching, and create more meaningful learning experiences for students.

B. METHODS

This study uses a qualitative descriptive approach to explore the self-training needs of prospective mathematics teachers in adapting mathematics software. The primary focus of this approach is to gain a deep understanding of the Digital Native Paradox phenomenon and the learning barriers experienced by the subjects in a naturalistic manner (Mejía, Martini, Grijalva, Larco, 2021).

1. Research Procedures

Systematically, the stages of this research are outlined in the order shown in Figure 1.

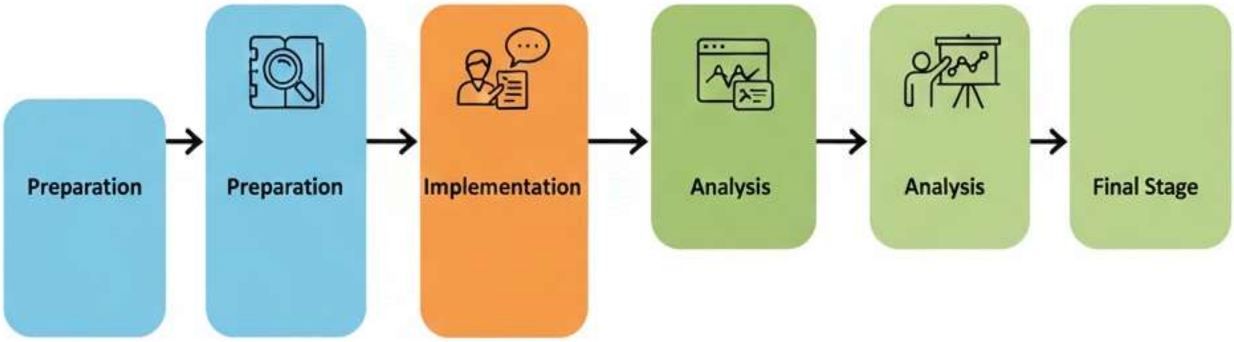

Figure 1. Research procedures

The population of this study were all final year students of the Mathematics Education Study Program at PGRI Wiranegara University who had taken technology-based learning courses. The sample was selected using a purposive sampling technique, with a total of 40 respondents filling out the questionnaire. Of these, six students were selected as key informants for in-depth interviews based on proficiency level criteria (high, medium, low) to obtain a variety of data.

2. Research Instrument

In carrying out this research, two main data collection instruments were used including: a training needs questionnaire and a semi-structured interview guide, both designed to gather comprehensive insight into participants' needs and experiences. To ensure the reliability and robustness of the data collected, the research instrument underwent a content validation process involving expert assessments from two specialists in mathematics education and learning technology (Zholymbayev, 2022). Their expertise is critical in refining the instruments to ensure that they effectively capture the necessary information. This research aims to ensure the validity of qualitative data through the application of source and method triangulation techniques, which involves comparing data collected from training needs questionnaires with statements collected from informants during semi-structured interviews to identify inconsistencies or areas that require further exploration. Additionally, the study included analysis of participants' digital work, providing an additional layer of validation by corroborating statements with concrete evidence of participants' abilities and experience. By using this triangulation technique, the study ensured a comprehensive understanding of participants' needs and confirmed the credibility of the findings, as shown in Table 1.

Table 1. Research Instrument Outline

Main Variables	Observation Indicators	Demand Dimensions
TPACK	Mastery of technical features and pedagogical integration of mathematics.	Technology Knowledge (TK), Technology Content Knowledge (TCK).
Independent Learning	The ability to plan, coordinate, and initiate independent learning.	Planning, Implementation, Self-Reflection.
Adaptation Software	Cognitive translation barriers and self-efficacy of new tool use.	Technology Anxiety, Resource Management.

3. Data Analysis

Data analysis is carried out through two main approaches to provide comprehensive results:

a. Descriptive Statistical Analysis (Quantitative Data)

Data from the questionnaire was processed using descriptive statistics to determine the percentage distribution of proficiency and levels of barriers (Wahyuni et al., 2025). The formula used was the percentage formula:

$$P = \frac{f}{N} \times 100\% \quad (1)$$

For Likert scale data, analysis is performed by calculating the average score (mean) using the formula $\bar{X} = \frac{\sum X}{N}$. Interpretation of the average score refers to the following criteria, as shown in Table 2.

Table 2. Interpretation of Average Scores (Mean)

Score Range	Interpretation Category
1.00 – 1.80	Very Low
1.81 – 2.60	Low
2.61 – 3.40	Currently
3.41 – 4.20	Tall
4.21 – 5.00	Very high

b. Interactive Model Analysis (Qualitative Data)

Qualitative data from interviews and observations were analyzed cyclically following the interactive model of Miles, Huberman, and Saldana (Maier & Robson, 2020) as shown in Figure 2.

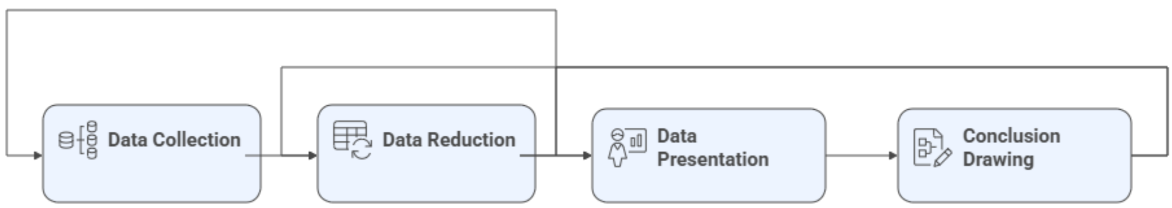

Figure 2. Analysis Process

The data reduction process is a crucial step in research analysis, where researchers code interview transcripts to differentiate data based on training need themes. This coding allows researchers to group information into specific categories, facilitating further analysis. For example, researchers assign specific codes to informant statements to distinguish between technical barriers, such as difficulties in scripting programming logic, and pedagogical barriers, such as difficulties integrating software features into calculus simulation materials. This process aims to coordinate the raw data without losing the essence of respondents' experiences, allowing researchers to focus on key elements relevant to the research objectives.

After data reduction, the next step is to organize it into a more structured form. Researchers use a descriptive matrix to map the relationship between the Digital Native Paradox phenomenon and the identified competency sets. This matrix serves to visualize the patterns of training needs that emerge among research subjects. By systematically presenting the data, researchers can easily see existing patterns and trends, thereby identifying areas requiring further attention.

The next step in the analysis process is drawing conclusions, where researchers formulate propositions based on a synthesis of quantitative data, such as the distribution of proficiency levels, and qualitative data, such as informants' narratives of needs. These conclusions aim to address the urgency of developing an independent training roadmap capable of bridging mathematical abstraction with digital functionality. With a deep understanding of the needs and challenges faced by research subjects, researchers can design more effective training programs that are tailored to actual needs. To ensure data validity (trustworthiness), this study employed source and technique triangulation techniques. Furthermore, member checking was conducted to ensure that the researcher's interpretations aligned with the participants' realities.

C. RESULT AND DISCUSSION

1. Research Results

Based on the analysis of data collected through surveys and in-depth interviews, three main findings were found regarding the need for independent training for prospective mathematics teachers in software adaptation. First, the Technical and Pedagogical Competency Gap. This finding indicates a sharp divide in capabilities between basic operational tools and complex content integration.

a. Basic Skills: Most participants (82%) demonstrated proficiency in routine software functions such as GeoGebra and Desmos. This includes graphing linear functions, plotting coordinate points, and using standard built-in functions.
b. Advanced Feature Barriers: Significant barriers arise when participants have to explore features that require logical algorithms, such as scripting for automation, visualizing 3D objects with dynamic parameters, and statistical modeling.
c. The Digital Native Paradox: These findings confirm the existence of the "digital native paradox"; although students are very familiar with communication technologies, they experience technical difficulties when confronted with the operational logic of scientific software that demands mathematical precision and understanding of program structure.

Second, the fragmentary self-regulated learning (SRL) profile. In the context of independent training, it was found that prospective teachers' learning strategies were still reactive and unplanned.

a. Trial and Error Strategy: Participants tend to experiment with features without reading the official documentation, which often ends in technical disappointment.
b. External Source Dependence: Most rely on short, task-oriented video tutorials (YouTube). They only look for ways to solve a specific problem without understanding the software architecture as a whole.
c. Roadmap Needs: There are gaps in the planning and self-evaluation stages. Prospective teachers need a self-paced training "roadmap" that explicitly links mastery of technical features to specific mathematical concepts in a logical sequence.

Third, Preferences for Learning Resources and Support. The analysis shows a shift in preferences from purely technical instruction to school-based, context-based guidance.

a. Project-Based Approach: Participants prefer project-based training modules that challenge them to solve real-life learning problems.
b. Classroom Case Simulations: Self-study materials that provide real-life classroom case simulations are needed to independently prove mathematical concepts.

2. Empirical Data and Visualization of Analysis Results

To strengthen the qualitative findings, the following presents quantitative data regarding the profile of the abilities and needs of prospective teachers. Data on the distribution of mathematical software feature proficiency levels among 100 respondents shows that most prospective teachers have mastered basic skills, but are still very weak in advanced features. In the aspect of 2D function graph visualization, as many as 88% of respondents are at the advanced level, while only 2% are still at the basic level. However, the percentage of proficiency drops drastically in the dynamic geometry construction feature, where only 35% are at the advanced level and the slider and animation feature at 25%. The gap is even more apparent in the complex 3D object visualization feature, where 50% of respondents are still at the beginner level. The most critical condition is found in the scripting and input programming features, where 80% of respondents are still at the basic/beginner level and only 4% are able to reach the advanced level, as shown in Figure 3.

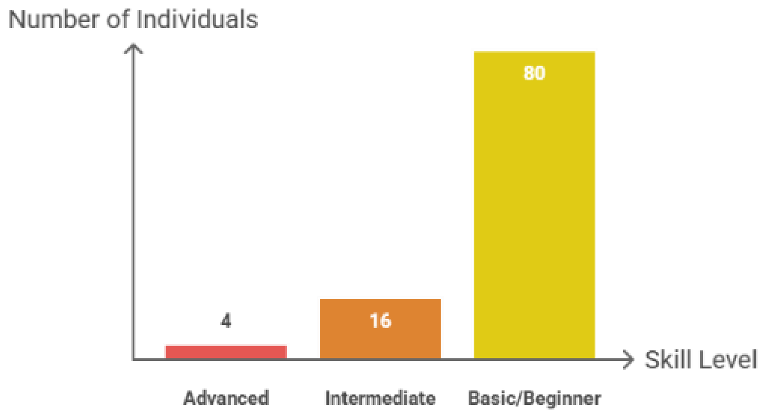

Figure 3. Visualization of Analysis Results

The graph above shows extreme disparity in advanced features (scripting), where 80% of prospective teachers are still at the beginner level, in stark contrast to the 2D visualization features which are dominated by the advanced level, as shown in Table 3 and Figure 4.

Table 3. Analysis of Major Barriers in Software Adaptation

Inhibiting Factors	Percentage	Category
Lack of systematic self-study guides	92%	Very high
Not linking tool features to open materials	85%	Tall
Technical complexity (programming language logic/input)	78%	Tall
Limited time for independent exploration	64%	Currently

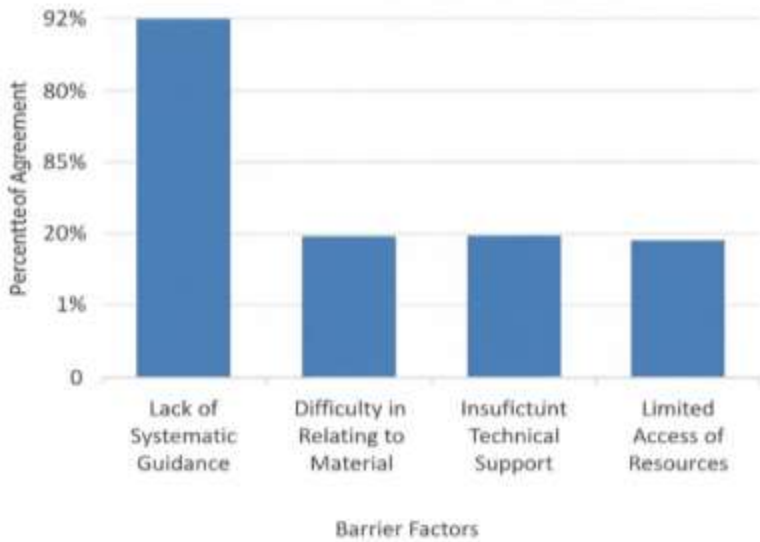

Figure 4. Barrier Bar Adaptation Graph

This bar chart identifies various inhibiting factors in adapting mathematics software, with the lack of systematic guidance being the most dominant obstacle, agreed to by approximately 92% of respondents. This figure far exceeds other obstacles such as difficulty connecting features to materials, lack of technical support, and limited access to resources, all of which were at a much lower level of agreement. This confirms previous findings that the primary problem for prospective teachers is not the lack of technology, but rather the lack of a clear training structure to bridge technical aspects into pedagogical practice. Thus, this data strengthens the argument that the success of "Adaptive Adaptation" outputs depends heavily on the provision of scaffolding or structured guidance capable of guiding prospective teachers' independent exploration into concrete instructional innovations, as shown in Table 4.

Table 4. Data Categorization Table

Main Theme	Code (Encoding)	Example of Respondent/Indicator Statements
Technical-Pedagogical Gap	Advanced Feature Gap	"I can graph functions, but I'm confused about using sliders for calculus simulations."
Independent Learning Pattern (SRL)	Reactive Learning	Study only when there is an assignment (PPL), not because of professional exploration.
Support needed	Pedagogical Scaffolding	"I need examples of how this feature is explained to students, not just how to click it."

This Table 4 provides an empirical basis that reinforces the urgency of the previous framework by highlighting that the primary obstacle for prospective teachers is no longer basic digital literacy, but rather a technical-pedagogical gap where they are able to operate features but struggle to relate them to advanced mathematical concepts such as calculus simulations. The findings regarding reactive learning patterns indicate that self-directed learning (SRL) motivation is still external due to task demands, rather than professional awareness, so they urgently need pedagogical support that focuses on strategies for delivering material to students rather than simply technical instructions on how to use the application. Overall, these data confirm that to achieve mature TPACK integration, the training process must shift from simply mastering tools to developing the ability to bridge technological features with the effective delivery of mathematical concepts in the classroom, as shown in Figure 5.

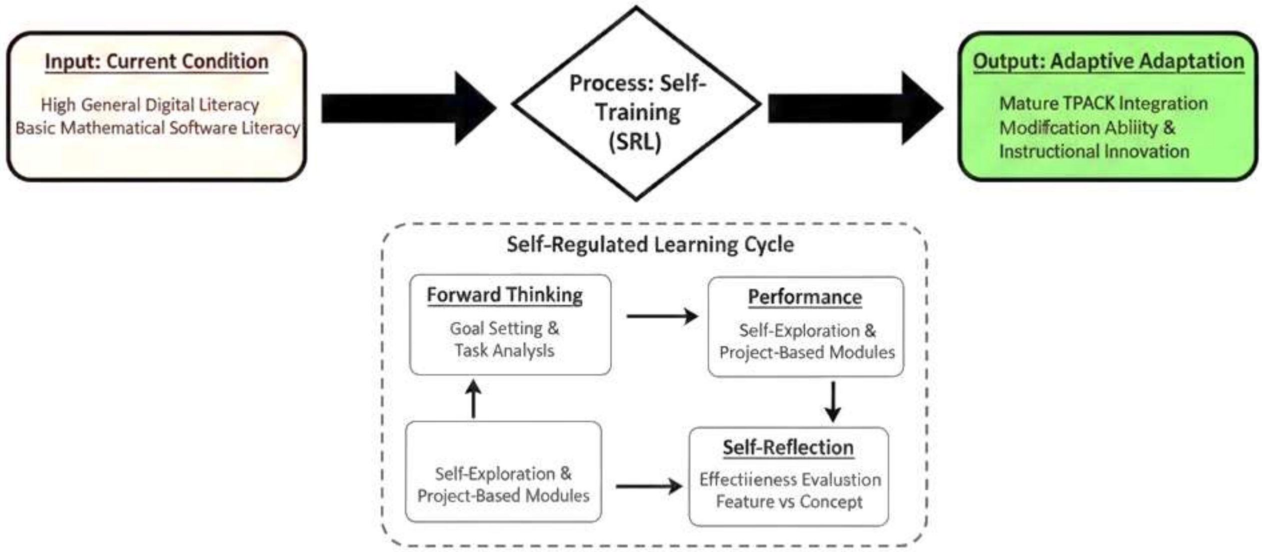

Figure 5. Software Adaptation Conceptual Model

Figure 5 illustrates the process of improving prospective teachers' competency in adapting mathematics software, starting with high general digital literacy but basic mathematical software literacy. Through a self-regulated learning (SRL)-based independent training process, prospective teachers go through a continuous cycle that includes goal planning, project-based exploration, and critical reflection on the effectiveness of technology features in conveying material concepts. The end result is an adaptive adaptation output, where teachers not only master the technology technically but also achieve TPACK integration maturity that enables them to make creative modifications and instructional innovations in mathematics learning.

3. Discussion

The results of this study demonstrate a stark contrast between basic technical skills and the ability to adapt to complex software. The finding that 88% of students are proficient in basic visualization but only 4% master advanced features (such as scripting) confirm the existence of the Digital Native Paradox in mathematics education. While student teachers may be familiar with technology, this proficiency is superficial and limited to the use of imaginative interfaces, as shown in Table 5.

Table 5. Comparison of TPACK Integration Levels Based on Findings

Aspect of Mastery	Real Condition (Findings)	Integration Target (Redefined)
Visualization	Static (2D Graph/Dot Plot)	Dynamic (Connected Variables & Parameters)
Data Manipulation	Enter manually one by one	Automation through Scripting
Concept Exploration	Limited to built-in features	Modify features for new proof

Referring to Ahmad & Nasution's (2022) research, which stated that software visualization automatically improves understanding, this study's findings instead criticize that without the adaptability of advanced features such as scripting and dynamic parameters, these visualizations remain merely statistical and fail to facilitate deeper cognitive exploration in students. This gap demonstrates that mastery of mathematical content does not necessarily guarantee mastery of the supporting digital tools.

a. The Digital Native Paradox: Consumption vs. Production

The Digital Native Paradox phenomenon discovered in this study presents a crucial point that challenges common assumptions. While today's prospective teachers are highly proficient in communication technology, there is a wide gap when it comes to using this technology for scientific purposes, as shown in Figure 6.

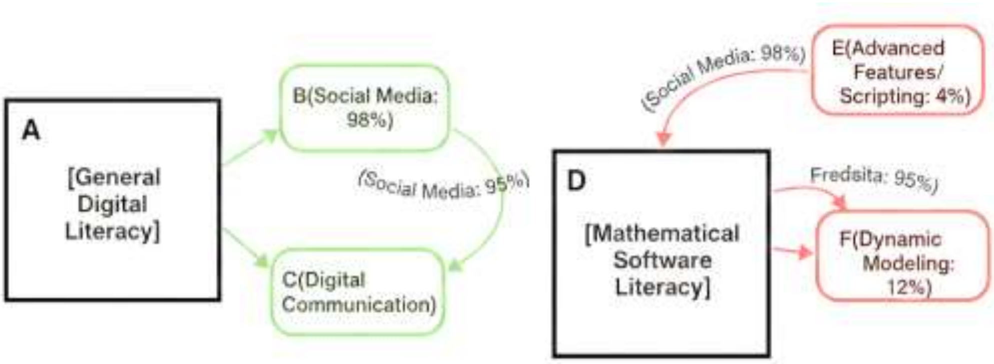

Figure 6. Digital Literacy of Prospective Teachers

In-depth analysis shows that prospective teachers are more proficient in Consumption Technology (using ready-made/intuitive applications) than in Production Technology (building mathematical models through code/input logic). This aligns with García-Sampedro et al.'s (2025) concerns about immature digital literacy. However, this study found that the primary barrier lies not in technology access, but rather in the inability to perform "cognitive translation" from mathematical language into software syntax. This inability creates a sense of technology anxiety that hinders innovation in classroom instruction.

b. Self-Regulation and the Effects of Cognitive Load

The low learning autonomy reflected in the Reactive Learning pattern indicates a fundamental weakness in Self-Regulated Learning (SRL). The finding that 92% of respondents who used a systematic guide indicated that prospective teachers experienced Extraneous Cognitive Load when trying to learn scripting or 3D modeling features without a clear roadmap, as shown in Figure 7.

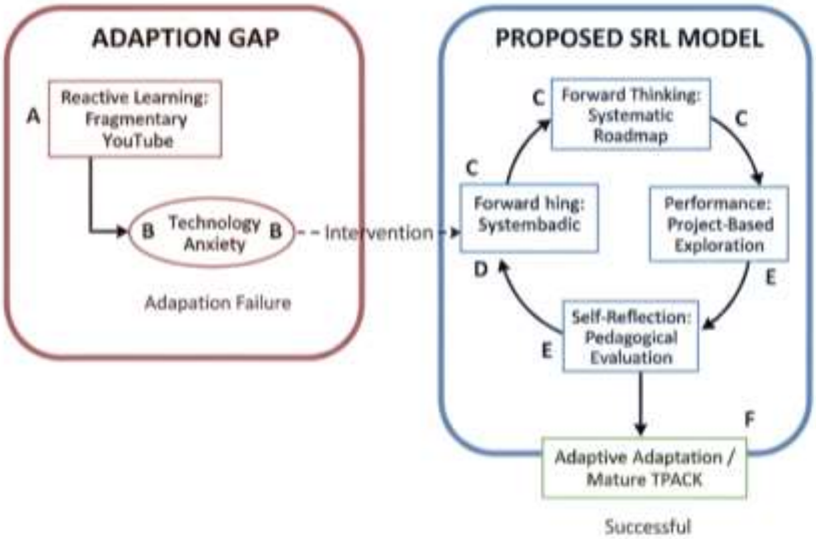

Figure 7. Software Adaptation Cycle through SRL

Unlike Hidayat & Putri's (2022) research, which emphasized the effectiveness of external training, this study argues that external training is only temporary if not accompanied by strengthening self-reflection. Prospective teachers who rely solely on fragmented YouTube tutorials lose the ability to diagnose errors (debug) in the models they create, leading them to feel technologically incompetent.

c. Reconstructing Learning Resources
Participants' preference for project-based modules and classroom case simulations (85% agreement) indicates a need for more specific pedagogical scaffolding. Studies by Li & Wang (2022); Smith (2022) tend to treat software as purely technical tools. In contrast, this study confirms that for preservice teachers, software is a pedagogical tool, as shown in Table 6.

Table 6. Shifting Needs for Learning Resources

Traditional Approach	Needs of Prospective Teachers (Findings)
Technical Operations Manual (Guidebook)	Pedagogical Scenario (Classroom Case)
Separate Feature Training	Content-Pedagogy-Technology Integration
Task-Based Tutorial (Task Oriented)	Multi-Level Challenge Module (Project Based)

d. Relationship with TPACK and Self-Regulated Learning (SRL)
Low adaptability to advanced features indicates weaknesses in the Technological Content Knowledge (TCK) component. Prospective teachers were unable to see how complex technical features could transform the way mathematical concepts were presented. Furthermore, the learning patterns observed were reactive and fragmented, indicating a low level of Self-Regulated Learning (SRL) strategies. Students only learned when faced with specific tasks, rather than through structured, independent learning plans. This aligns with the findings of Viberg et al. (2020) that successful technology

integration requires a high level of learning independence to explore the full potential of digital tools.

e. Implications for Institutions

The novelty of this research lies in the understanding that successful self-paced training must begin with a shift in student identity, from "passive users" to "dynamic content developers." These findings provide strategic implications for Teacher Training Institutions to reconstruct their technology mentoring model through four main pillars: First, Redesign the Curriculum Based on Digital Pedagogy. Institutional Teacher Training Institutions need to shift the focus of learning technology courses from teaching technical features (tool-centric) to integrating features into learning scenarios (pedagogy-centric). The curriculum should require exploration of advanced features such as scripting through final-course projects, so students become accustomed to dealing with technical complexity from an early age. Second, provide an asynchronous microlearning ecosystem. Given that 64% of respondents complained about time constraints, the recommends building a self-study resource repository based on microlearning. This repository should be designed hierarchically and interactively, providing a clear "roadmap" from basic to advanced levels, thereby reducing students' cognitive load when conducting independent exploration outside of formal class hours.

Third, strengthening the character of self-regulated learning (SRL). Institutions cannot simply provide software; they must also train lecturers to model self- regulation. Lecturers need to guide students in diagnosing their own learning needs, setting weekly technology learning goals, and critically reflecting on the effectiveness of the digital tools they adapt. Fourth, an Authentic Project-Based Assessment System. To transform students into content developers, the evaluation system must shift from technical standardized exams to the creation of digital artifacts ready for use in practice schools. This will strengthen prospective teachers' sense of self-efficacy, as they feel capable of generating innovative solutions to real-world problems in mathematics classrooms. Thus, the role of Institute for Teacher Education is not merely as a transmitter of information, but also as an accelerator of future prospective teachers' professional autonomy.

Theoretically, this research extends the application of SRL theory to the specific technology domain of mathematics. Software adaptation is not simply a technical issue, but rather a cognitive regulation process for diagnosing one's own learning needs. By strengthening the performance phase through project-based self-exploration, prospective teachers can achieve more sustainable TPACK maturity. In conclusion, the current need for self-training centers on the availability of a "roadmap" that bridges mathematical abstraction with digital functionality.

D. CONCLUSION AND SUGGESTIONS

This study concluded that there is a significant competency gap among prospective mathematics teachers in adapting to instructional software. Despite being classified as digital natives, most students (88%) only master basic visualization features, while their ability to perform advanced customizations such as scripting and dynamic modeling remains very low

(4%). This is due to unstructured and fragmented self-learning patterns, which actually increase students' cognitive load. Practically, this study recommends the development of a systematic, project-based "Self-Training Roadmap" for prospective teachers. Self-training should be directed at transitioning from simple technical understanding to complex pedagogical integration. Recommendations for educational training institutions include the importance of integrating a Self-Regulated Learning (SRL) framework into technology-based curricula, so that prospective teachers have the ability to continuously adapt to future developments in mathematics software.

REFERENCES

Abror, M. H. (2022). Self-Regulated Learning Terhadap Hasil Belajar Matematika Siswa. *Plus Minus: Jurnal Pendidikan Matematika*, *2*(2), 233–242. https://doi.org/10.31980/plusminus.v2i2.1100

Adhya, D. H., & Panda, S. (2026). An integrative systematic review analysis of research on technology - enabled personalized learning and self - regulated learning. *Smart Learning Environments*, *13*(3), 2–26. https://link.springer.com/article/10.1186/s40561-025-00428-8

Adipat, S. (2021). Developing Technological Pedagogical Content Knowledge (TPACK) through Technology-Enhanced Content and Language-Integrated Learning (T-CLIL) Instruction. *Education and Information Technologies*, *26*(5), 6461–6477. https://doi.org/10.1007/s10639-021-10648-3

Amelia, R. (2025). Mathematical Critical Thinking Ability Reviewed from Self-Regulated Learning : Systematic Literature Review. *Anatolian Journal of Education*, *10*(1), 91–102. https://eric.ed.gov/?id=EJ1467021

Cevikbas, M., Kaiser, G., & Schukajlow, S. (2022). A systematic literature review of the current discussion on mathematical modelling competencies: State-of-the-art developments in conceptualizing, measuring, and fostering. *Educational Studies in Mathematics*, *109*(2), 205-236. https://doi.org/10.1007/s10649-021-10104-6

Christina Khaidir, Ahmad Fauzan, Arnellis, Mega Iswari, S. (2026). Local Instructional Theory of Definite Integral Learning to Improve Prospective Mathematics Teachers ' Mathematical Problem-Solving Skills and Self-Regulated Learning. *International Research Journal of Multidisciplinary Scope*, *7*(2), 532–544. https://doi.org/10.47857/irjms.2026.v07i01.09499

Frohlich, J. R., Goegan, L. D., & Daniels, L. M. (2020). Practicing teachers' attributions for the behaviour of students with learning disabilities and attention- deficit/hyperactivity disorder. *Alberta Journal of Educational Research*, *66*(3), 250–268. https://doi.org/10.55016/ojs/ajer.v66i3.56950

García-Maza, S. (2025). Technical–Economic Assessment and FP2O Technical–Economic Resilience Analysis of the Gas Oil Hydrocracking Process at Large Scale. *Sci*, *7*(1), 334–345. https://doi.org/10.3390/sci7010017

Hsu, Y. Y. (2020). Evaluating the effectiveness of a preservice teacher technology training module incorporating SQD strategies. *International Journal of Educational Technology in Higher Education*, *17*(1). https://doi.org/10.1186/s41239-020-00205-2

Lämsä, J., Mooij, S. De, Baars, M., & Molenaar, I. (2026). Self-Regulated Learning, Multimodal Data, and Analysis Grid: Where Are We Now and Where Are We Going? *Educational Psychology Review*, *7*(2), 1–10. https://link.springer.com/article/10.1007/s10648-025-10113-4

Liao, M. L., Yeh, C. C., Lue, J. H., Chien, C. L., Hsu, S. H., & Chang, M. F. (2022). Benefits of a bilingual web-based anatomy atlas for nursing students in learning anatomy. *BMC Medical Education*, *22*(1), 341. https://doi.org/10.1186/s12909-022-03405-8

Maier, R., & Robson, K. L. (2020). Exploring university-to-college transfer in Ontario: A qualitative study of non-linear post-secondary mobility. *Canadian Journal of Higher Education*, *50*(1), 82–94. https://doi.org/10.7202/1069653ar

Matthew, U. O. (2022). Educational Technology Adaptation & Implication for Media Technology Adoption in the Period of COVID-19. *Journal of Trends in Computer Science and Smart Technology*, *4*(4), 226–245. https://doi.org/10.36548/jtcsst.2022.4.002

Mejía, P., Martini, L. C., Grijalva, F., Larco, J. C., & ... (2021). A survey on mathematical software tools for visually impaired persons: A practical perspective. *IEEE ...*, *9*(2), 66929–66947. https://ieeexplore.ieee.org/abstract/document/9417177
Melo-Pfeifer, S. (2022). Transforming Disinformation on Minorities Into a Pedagogical Resource: Towards a Critical Intercultural News Literacy. *Media and Communication*, *10*(4), 338–346. https://doi.org/10.17645/mac.v10i4.5708
Mukamba, E., & Makamure, C. (2020). Integration of GeoGebra in teaching and learning geometric transformations at ordinary level in Zimbabwe. *Mathematics and Science Education*, *1*(1), 2–8. https://doi.org/10.30935/conmaths/8431
Nazaretsky, T. (2022). Teachers' trust in AI-powered educational technology and a professional development program to improve it. *British Journal of Educational Technology*, *53*(4), 914–931. https://doi.org/10.1111/bjet.13232
Oner, D. (2020). A virtual internship for developing technological pedagogical content knowledge. *Australasian Journal of Educational Technology*, *36*(2), 27–42. https://doi.org/10.14742/ajet.5192
Özçakır, B., Özdemir, D., & Kıymaz, Y. (2020). Effects of dynamic geometry software on students' geometric thinking regarding probability of giftedness in mathematics. *International Journal of Contemporary Educational Research*, *7*(2), 48-61. https://doi.org/10.33200/ijcer.664985
Qiu, C. a. (2022). Pre-service teachers' perceptions of technological pedagogical content knowledge in mainland China: A survey of teachers of Chinese as a second language. *Education and Information Technologies*, *27*(5), 6367–6391. https://doi.org/10.1007/s10639-022-10888-x
Rahim, N., Nesar, S., Mumtaz, T., Naeem, S., & Ali, M. S. (2022). Validation of questionnaire regarding online teaching (QOT) during Covid-19 in Karachi, Pakistan. *PLOS ONE*, *17*(9 September), 22–30. https://doi.org/10.1371/journal.pone.0274268
Ramadhani, W., Maryani, I., & Vehachart, R. (2022). Literature Study on Self-Regulated Learning in Science Learning of Elementary School Students. *International Journal of Learning Teaching and Educational Research*, *1*(02), 80–100. https://doi.org/10.56741/ijlree.v1i02.71
Rosnelli. (2023). Independent Curriculum Learning Management to Improve Students' Literacy and Numerical Competence in Schools. *International Journal of Education in Mathematics Science and Technology*, *11*(4), 946–963. https://doi.org/10.46328/ijemst.3513
Shinta, O., & Agoestanto, A. (2025). Kemampuan Literasi Matematika Dan Self- Regulated Learning Siswa Pada Model. *Prisma*, *8*(1), 283–292. https://proceedings.unnes.ac.id/prisma/article/view/4326
Sudatha, I. G. W., & Agustini, K. (2026). *Implikasi Pedagogis Alat Kreasi Visual-Digital terhadap Kompetensi 4C dan Literasi Digital : Tinjauan Sistematis*. *15*(1), 499–518. https://doi.org/10.58230/27454312.3705
Tesfamicael, S. A. (2022). Prospective teachers' cognitive engagement during virtual teaching using GeoGebra and Desmos. *Pythagoras*, *43*(1), 1-15. https://doi.org/10.4102/PYTHAGORAS.V43I1.691
Velten, K., Schmidt, D. M., & Kahlen, K. (2024). *Mathematical modeling and simulation: introduction for scientists and engineers*. books.google.com.
Viberg, O. (2020). Validating an instrument to measure teachers' preparedness to use digital technology in their teaching. *Nordic Journal of Digital Literacy*, *15*(1), 38–54. https://doi.org/10.18261/ISSN.1891-943X-2020-01-04
Viberg, O., Grönlund, Å., & Andersson, A. (2023). Integrating digital technology in mathematics education: a Swedish case study. *Interactive Learningw*, *31*(1), 232–243. https://doi.org/10.1080/10494820.2020.1770801
Wahyuni, S. F., Sari, M., Astuty, W., Lestari, S. P., & Hafas, H. R. (2025). Determinants of Personal Financial Management: Exploring The Mediating Role of Locus of Control Among Multigenerational Caregivers in Medan. *Journal of International Conference Proceedings*, *8*(1), 32–42. https://doi.org/10.32535/jicp.v8i1.3978
Widana, I. W. (2020). Meta-Analysis : The Relationship Between Self- Regulated Learning And Mathematical Critical Reasoning. *Education Innovation Diversity (EID)*, *1*(4), 64–75. https://doi.org/10.17770/eid2022.1.6739
Yani, T. A. (2025). Examining the relationship between mathematical literacy and digital literacy among

pre-service mathematics teachers. *Eurasia Journal of Mathematics Science and Technology Education*, *21*(5). https://doi.org/10.29333/ejmste/16392

Yin, J. (2021). Conversation Technology With Micro-Learning: The Impact of Chatbot-Based Learning on Students' Learning Motivation and Performance. *Journal of Educational Computing Research*, *59*(1), 154–177. https://doi.org/10.1177/0735633120952067

Zholymbayev, O. (2022). Training teachers in science subjects through STEAM technologies. *World Journal on Educational Technology Current Issues*, *14*(4), 1197–1204. https://doi.org/10.18844/wjet.v14i4.7707

Zou, D. (2021). Digital game-based learning of information literacy: Effects of gameplay modes on university students' learning performance, motivation, self-efficacy and flow experiences. *Australasian Journal of Educational Technology*, *37*(2), 152–170. https://doi.org/10.14742/AJET.6682