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Assessing the Competence of Prospective Mathematics Teachers in Technology-Enhanced Differentiated Instruction for Inductive Learning

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Abstract

The demands of 21st-century pedagogical competencies necessitate that Prospective Mathematics Teachers (PMTs) be proficient in the integrated application of technology and differentiation. This study aims to assess the competence of PMTs in implementing technology-enhanced differentiated instruction within an inductive learning framework, evaluated through seven key elements referencing the frameworks of Prince & Felder and Tomlinson. Utilizing a descriptive qualitative approach, this study analyzed in-depth peer teaching video recordings from the entire cohort of 15 students in a mathematics education program. The novelty of this research lies in its focus on the integrated operationalization of these three complex pedagogical elements. Data analysis was conducted rigorously using the interactive model of Miles, Huberman, and Saldana, supported by source triangulation to ensure the credibility of the findings. The results indicate that PMTs achieved high competence in inductive learning and differentiation (implemented by 93%–100% of PMTs). However, the implementation of technology-enhanced learning showed significant variance, being adequately achieved by only 67% of PMTs. It is concluded that while PMT training is robust in instructional design and differentiation strategies, the integration of technological tools requires further optimization and focused development to meet the demands of 21st-century skills.

Keywords: differentiated instruction, prospective mathematics teachers, technology-enhanced inductive learning

INTRODUCTION

The 21st century demands fundamental changes in educational practices, particularly in mathematics learning. Instruction needs to be directed toward implementations that develop essential 21st-century skills, including communication, collaboration, critical thinking, and creativity. These skills must be integrated with technical, information, and problem-solving abilities (Sulaiman & Ismail, 2020; van Laar, van Deursen, van Dijk, & de Haan, 2020), integrated with digital skills (Sulaiman & Ismail, 2020; van Laar, van Deursen, van Dijk, & de Haan, 2017; van Laar et al., 2020). Therefore, the adoption of learning models that effectively support the development of these competencies must be prioritized. Previous research highlights various models capable of developing 21st-century skills, such as STEM-based digital learning (Zainil, Kenedi, Rahmatina, Indrawati, & Handrianto, 2023), inquiry learning (Prayogi, Muhali, Sri Putu Verawati, & Asy'ari, 2016), and project-based learning (Hanida, Rachmadiarti, & Susantini, 2023).

Inductive learning is one pedagogical approach that can develop 21st-century skills. Unlike traditional methods that begin with general principles, inductive learning starts with specific elements, such as a set of observational data, a case study, or a complex real-world problem. In this process, students analyze data or scenarios to identify relevant facts, rules, procedures, and guiding principles (Prince & Felder, 2006). They are either presented with the necessary information or actively guided to discover it themselves, fostering deeper engagement and critical thinking.

In the 21st century, the integration of digital devices into the learning process has become a necessity. Technology-enhanced learning plays a crucial, multifaceted role in mathematics education by enhancing the exploration and visualization of complex mathematical concepts. Botzakis (2017) emphasized that technology can act both as a teaching tool and as a medium that enriches students' experiences in learning mathematics by facilitating interaction with complex ideas through visual aids and simulations. Furthermore, interactive simulations and digital manipulatives allow students to visualize abstract concepts more concretely (Timotheou et al., 2023). For example, using tools like Google Sheets can aid in understanding complex mathematical relationships, such as the properties of the sine function (Dung & Nhi, 2024). However, effective implementation depends on the technology being seamlessly integrated into educational practices to support mathematical exploration (Drijvers, 2015).

In contemporary education, addressing the diversity of students' abilities, learning styles, and interests presents a significant challenge. This heterogeneity necessitates differentiated instruction, which ensures that each student receives support and challenges tailored to their individual learning needs (Smets & Struyven, 2020). Differentiated instruction is crucial because it customizes the learning process to diverse student characteristics, facilitating the development of higher-order thinking competencies (Pramesti, Dewi, & Alias, 2024).

It can be implemented based on process, product, and content (Chien, 2015; Sulistianingrum, Fauziati, Rohmah, & Muhibbin, 2023; Tomlinson, 2001). ne example of differentiation involves constructing questions with varying levels of difficulty, allowing students to engage with the material at their appropriate skill level (Hatmanto & Rahmawati, 2023) is an example of learning differentiation. This approach fosters an inclusive atmosphere and increases engagement by respecting varied learning paces and styles.

Integrating inductive learning, technology, and differentiated instruction creates a powerful pedagogical synergy essential for preparing PMTs. In this framework, inductive learning provides the discovery structure, while technology-enhanced learning serves as the critical enabler for effective differentiated instruction. Inductive learning builds understanding through discovery, and technology-enhanced learning methods, such as augmented reality or interactive applications (Sudirman, Kusumah, & Martadiputra, 2021), strengthen student motivation and concept acquisition. Furthermore, the use of technology facilitates differentiation by simplifying the management of varied learning pathways and levels of complexity required by inductive exploration. Platforms like Scratch and GeoGebra (Daher, Baya'a, Jaber, & Shahbari, 2020; Putra, Hermita, Alim, Dahnilsyah, & Hidayat, 2021), have proven effective in increasing engagement and enabling students to learn at their own pace and level, thus directly supporting the differentiated approach. Therefore, PMTs must be trained to navigate this complex interaction and design unified instruction where technology is intentionally used to manage the pedagogical tension between providing structured discovery and accommodating student heterogeneity.

However, existing research typically focuses on pairwise integrations (e.g., technology in inductive learning or technology for differentiation). While many studies address how technology supports mathematics learning (Carriazo-Regino et al., 2024; Dũng & Nhi, 2024), or how inductive learning improves conceptual understanding (Prince & Felder, 2006), the literature is notably silent on how PMTs operationalize the synergy described above—specifically, how they design lessons where technology mediates the differentiation needs within the structure of inductive discovery. This leaves an empirical gap regarding the practical competence of pre-service teachers in managing these three concurrent demands.

The novelty of this research lies in its holistic and integrated assessment. This study aims to evaluate the specific competence criteria—developed from the synthesis of Prince & Felder and Tomlinson's frameworks—to determine the extent to which PMTs are able to implement the required differentiated instruction approach within technology-enhanced inductive learning designs, providing an analytical measure of their readiness for 21st-century classrooms.

This gap constitutes the novelty of this research. Unlike previous studies which examined these concepts in isolation, this study specifically measures the competency of PMTs in integrating all three components simultaneously within a unified design. This research assesses not only the functional use of technology-enhanced learning to support inductive discovery, but also the extent to which PMTs accommodate diverse student needs through differentiated instruction in the process. This unique integration provides a holistic view of instructional readiness, offering a significant contribution by providing specific empirical data on the challenges and successes of PMTs in designing complex, relevant instruction to meet 21st-century demands.

This study therefore aims to evaluate the extent to which PMTs are able to implement a differentiated instruction approach within technology-enhanced inductive learning designs. Through an in-depth, criteria-based analysis of peer teaching videos, this research will identify explicit patterns, strengths, and areas for development, providing targeted recommendations for the mathematics teacher education curriculum and future research focus.

METHODS

Types of Research

This research employed a descriptive qualitative design. This approach is appropriate because it focuses on describing and analyzing Prospective Mathematics Teachers' (PMTs) competencies in implementing technology-enhanced differentiated instruction within inductive learning. This methodology allows for a rich and contextual understanding of how **PMTs** integrate and practice these three learning elements.

Research Setting and Participants

The research was conducted from February to August 2025 in Salatiga City, Central Java Province, Indonesia. The research participants were 15 sixth-semester students in the Mathematics Education Study Program at UIN Salatiga. These students, as PMTs, had completed a series of relevant courses, including mathematics lesson planning, methodology, evaluation, and microteaching. Data collection was conducted at the end of the microteaching course, where participants implemented lesson plans through teaching simulations (*peer teaching*). The sample size of $N = 15$ was chosen using a purposive sampling method. This number represents the entire cohort of students enrolled in the final microteaching course for that semester who had met the prerequisite competencies for implementation assessment.

The study received ethical approval from the Institutional Review Board (IRB) of UIN Salatiga. Informed consent was obtained from all 15 PMTs for the use of their peer teaching video recordings for research purposes, with the assurance of anonymity and confidentiality. All participants were informed of their right to withdraw at any point. Anonymization procedures were strictly followed, and participants are identified only by initials (e.g., RRA, NAW) throughout the manuscript.

Research Procedures

This research was conducted through four main stages: data collection, data reduction, data presentation, and conclusion drawing and verification. During the data collection stage, video recordings of teaching practices from the 15 PMTs were collected. During the data reduction stage, the videos were repeatedly watched and reviewed to gain an initial understanding of the data content. Segments of learning activities were focused on based on: the characteristics of inductive learning (Prince & Felder, 2006, 2007), the use of technology (type and function), and differentiation strategies (content, process, product). Initial codes were compiled, grouped into broader categories, and then irrelevant data were selected and discarded. Irrelevant data, such as simple non-instructional classroom management or non-sequitur discussions, were discarded. Coding decisions focused strictly on instructional segments where the PMT made explicit pedagogical choices related to the three observed elements.

In the data presentation stage, the reduced data were presented in tabular form for easier understanding and interpretation. In the conclusion-drawing and verification stage, initial conclusions were drawn by identifying recurring patterns and themes. Verification was conducted continuously by returning to the raw data. Triangulation was performed by comparing the findings from the video data with the content of the PMTs' teaching modules to check for alignment between planned and enacted instruction.

Data and Data Collection Instruments

The data in this study consisted of videos of teaching practices (*peer teaching*). The data were analyzed using an instrument in the form of a checklist designed for implementing technology-enhanced differentiated instruction for inductive learning. (Prince & Felder, 2006, 2007). The checklist was constructed based on a synthesis of three core theoretical frameworks: (1) Inductive Learning (5 characteristics based on Prince & Felder, 2006); (2) Differentiated Instruction (3 dimensions: content, process, and product, based on Tomlinson's framework); and (3) Technology Integration (type and functional use). To ensure rigor, the instrument's content validity was established by expert review from three experienced experts in mathematics education and educational technology. Their feedback ensured alignment between the checklist items and the theoretical constructs being measured.

The checklist used the Guttman scale: a **"yes"** was indicated if an observation element was implemented, and a "no" if it was not implemented (correcting the ambiguity noted by the reviewer). Adequate competence was operationally defined as the PMT successfully implementing at least 5 out of 7 core checklist elements (an achievement threshold of approximately 71% or higher). This ensured that PMTs who only achieved minimal technology integration (67%) were not categorized as fully competent unless their performance in the other six elements was perfect.

Data Analysis

The data in this study were analyzed using the interactive model (Miles, Huberman, & Saldana, 2014) which involves three interrelated activities: data reduction, data presentation, and conclusion drawing/verification. Following the collection of data on the PMTs' ability to implement technology-enhanced differentiated instruction for inductive learning, data reduction was carried out to select only data relevant to the research objectives. The reduced data were then subjected to data presentation in tabular form for easier interpretation. In the conclusion drawing and verification stage, initial conclusions were drawn by identifying recurring patterns, key themes, and relationships between categories from the presented data. Verification was carried out by comparing initial conclusions with the raw data. Triangulation was conducted by comparing data from the practice videos with data in the PMTs' lesson plans.

RESULTS AND DISCUSSION

The results describe the competence of Prospective Mathematics Teachers (PMTs) in implementing technology-enhanced differentiated instruction within an inductive learning framework. The analysis is structured thematically based on the three core components measured. The level of competence for the 15 PMTs, analyzed via video observation checklists, is summarized in Table 1.

Table 1. Tabulation of Implementation of Technology-Enhanced Differentiated Instruction for Inductive Learning

No.	Identified Elements	Percentage of Implementation
1.	from the specific to the general	93%
2.	learner-centered	100%
3.	Students build their own understanding or formulate their own concepts from the results of exploration	93%
4.	connecting new knowledge with prior knowledge	100%
5.	involve active learning	100%
6.	technology-enhanced learning	67%
7.	differentiated instruction	100%

Table 1 shows that 93% of PMTs were able to implement the elements of moving from the specific to the general and students constructing their own understanding. All PMTs successfully implemented learner-centeredness, connecting new knowledge with prior knowledge, involving active learning, and differentiated instruction. Only 67% of PMTs were able to implement technology-enhanced learning.

Inductive Learning Competence

PMTs demonstrated high competence in the core characteristics of inductive learning (93% - 100% success rate).

Moving from Specific Cases to General Concepts

High implementation (93%) was observed in the element of starting learning from the specific to the general. For example, PMT RRA introduced relations and functions by presenting a contextual problem about vehicle license plates and regions, "Have the children ever seen a vehicle license plate? Is the vehicle license plate a set? If the vehicle starts with H, where does it come from? If it starts with AB, which region does it come from? If the vehicle license plate and region are, can they be identified as a relationship between sets? Does each vehicle have a different vehicle number from other vehicles?" The student answered, "Yes". This problem orientation, aligned with the first syntax of Problem Based Learning (PBL), conditions students to connect real-life problems to the mathematical concepts abilities (Agustarina, Zulkardi, Putri, & Susanti, 2021). The use of contextual problems aligns perfectly with inductive learning, where teaching begins with specific elements (case studies or real-world problems) to guide students toward the facts and principles themselves (Prince & Felder, 2006, 2007).

The following is a picture showing the learning situation in the video as in the figure 1:

Figure 1. RRA Presents Contextual Problems at the Beginning of Learning

Conversely, the 7% of PMTs who struggled with this element demonstrated a tendency toward deductive teaching. For instance, PMT NAW's dialogue on an arithmetic sequence immediately presented the general formula $U_n = a + (n-1)b$ after a simple pattern identification. This transition provided the rule too early, bypassing the student discovery phase (Prince & Felder, 2006, 2007). This is shown in the following figure:

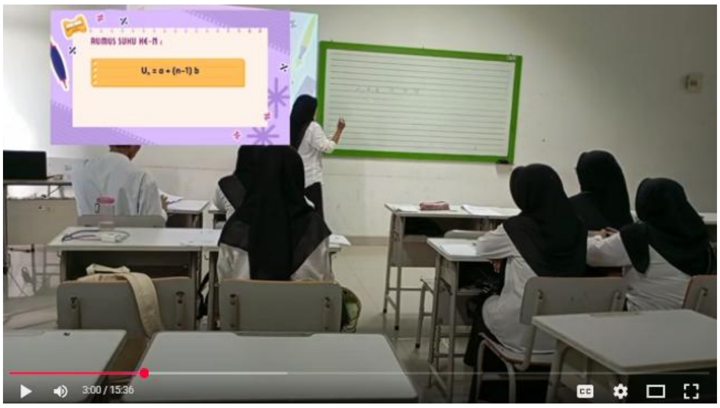

Figure 2. NAW Presents General Formulas at the Beginning of Learning

The following is an excerpt of dialogue obtained from a video recording of the practice by NAW:

NAW	:	*"If mother has the numbers 2, 5, 8, … Can you name the third number after 8?*
Learners	:	*"11, 14, 17"*
NAW	:	*"How can you determine the numbers 11, 14, 17 from where?"*
Learners	:	*"From plus 3"*
	:	*"If you were asked to find the 10th number, would you be able to determine it? You could determine it using a formula, namely* $U_n = a + (n-1)b$*, , where Un is the nth order, a is the initial number or the first number. The number b is the difference or difference. For example, if we want to find U_6 from the question, then U_6 is 2+(6-1)3 which is equal to 17"*

Through the dialogue excerpt, it is known that the problem is in the form of an arithmetic sequence and immediately presents the formula for the nth term to determine the 6th term. This tends towards deductive teaching, namely the teacher first teaches the relevant mathematical theory and models to students, then moves on to exercises from the textbook, and finally perhaps arrives at real-world applications (Prince & Felder, 2007).

Learner-Centered and Concept Construction

Learner-centered and concept construction includes (1) learner-centered learning, (2) active learning, (3) connecting prior knowledge, and (4) concept construction. In this session, one of the subjects, RRA, directs students to discuss in groups of three based on the results of the diagnostic assessment. RRA facilitates students to work in groups using student worksheets (LKPD). The LKPD contains instructions for discussion and investigation. Throughout the discussion and investigation process, the teacher circulates to monitor the progress of the discussion. The teacher also directs the investigation process to ensure it aligns with the learning objectives. This is relevant to the characteristics of inductive learning, which does not begin with general principles (Prince & Felder, 2006, 2007). In inductive learning, students are directed to collaborate in interpreting a set of observational or experimental data, analyzing a case study, or solving a complex real-world problem.

Active learning, as an element, requires students to physically move, discuss, manipulate objects/data, or interact cognitively, ensuring sufficient time is allotted for these activities. RRA implemented active learning by facilitating students' discussions, investigations, and problem solving. The learning setting used is group work, which encourages collaboration among students. Students work using worksheets structured according to PBL syntax.

Connecting new knowledge with prior knowledge is characterized by instructions or questions designed to guide students in linking new concepts to their existing knowledge base. RRA practiced learning with the following goal: "Students can identify and state everyday problems or situations that are relational and functional." RRA presented a situation to connect new knowledge, namely the concepts of relations and functions, with prior knowledge, namely the concept of sets. The following is an excerpt from the dialogue between RRA and students:

RRA	:	*"Did the children know before or not, what a set is?"*
Learner	:	*"Not yet"*
RRA	:	*"Let's recall. A set is a clearly defined group of people, objects, or other things. For example, if there's a group of beautiful women in class E, is that a set?"*
Learner	:	*"No"*
RRA	:	*"Why?"*
Learner	:	*"Because everyone is beautiful"*
RRA	:	*"It's not a set because everyone's measure of beauty is different. If the statement is like this: a collection of four-legged animals. Is it a set?"*
Learner	:	*"Yes"*
RRA	:	*"That's right. The group of four-legged animals is a set because it can be clearly defined as which animals have four legs."*

The next elemen addresses students constructing their own understanding or formulating concepts based on their explorations. There's a session for the teacher to confirm or refine the concepts after the students have attempted to construct their understanding. After students worked in groups to understand the concepts of relations and functions, RRA directed students to conduct presentations. The presentation session demonstrated the syntax for developing and presenting work in PBL. Students presented their discussion results in writing and were then asked to present them orally to receive feedback from the teacher.

Implementation of Differentiated Instruction

All PMTs (100%) successfully implemented differentiated instruction, based on diagnostic assessments of learning styles or cognitive abilities. The observed differentiation primarily took the form of content differentiation. For example, PMT RRA varied the complexity of problems in the worksheets; students with high abilities received more complex problem contexts, accommodating differences in academic ability (Hatmanto & Rahmawati, 2023). This high rate of implementation confirms the PMTs' commitment to accommodating student diversity (Tomlinson, 2001). However, critical reflection suggests this proficiency was often limited to content and process differentiation, highlighting that future training should encourage PMTs to explore more structural forms of differentiation, such as product or assessment choice, to ensure the depth and quality of differentiation moves beyond superficial strategies.

For example, PMT RRA varied the complexity of problems in the worksheets; students with high abilities received more complex problem contexts, accommodating differences in academic ability Differentiation is followed up based on a diagnostic assessment of students' learning styles or cognitive abilities. This element is implemented as shown in Figure 3 below:

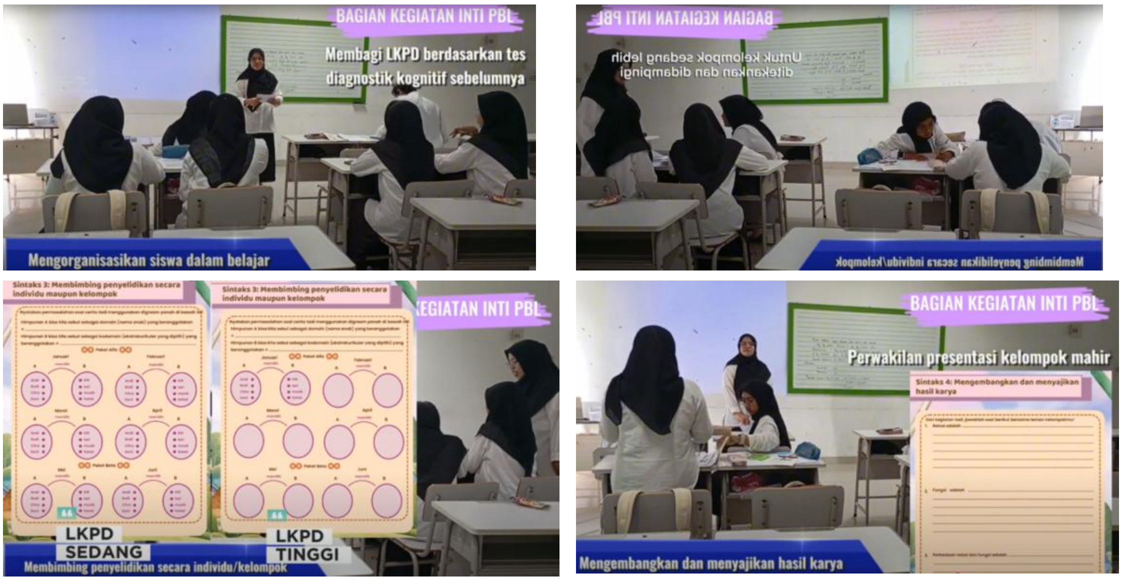

Figure 3. Documentation of Implementation of Differentiated Instruction

During peer teaching, RRA implements content differentiation by varying the content of its worksheets. In the worksheets for students with moderate abilities, RRA presents problems with relatively simple contexts. However, for students with high abilities, RRA provides worksheets with more complex problem contexts. This is done to accommodate the differences in academic ability that have been mapped through diagnostic assessment results.

Implementation of Technology-Enhanced Learning

Technology-enhanced learning showed the lowest implementation rate (67%), highlighting an inconsistent technological competence across the cohort. The variance suggests a gap in practical, high-quality technology training. Successful integration involved using technology functionally to support exploration. PMT IRL, for instance, utilized **GeoGebra** software to facilitate students in exploring the concept and properties of prisms (e.g., via the link https://www.geogebra.org/m/ksvrv2xy). The use of this software allowed students to visualize objects and conduct simulations, aligning with the literature on using technology as a visualization tool to enhance conceptual understanding (Drijvers, 2015). Other applications included Canva and Google Forms for presentation and assessment. The Figure 4 illustrates the implementation of technology-enhanced learning by PMTs:

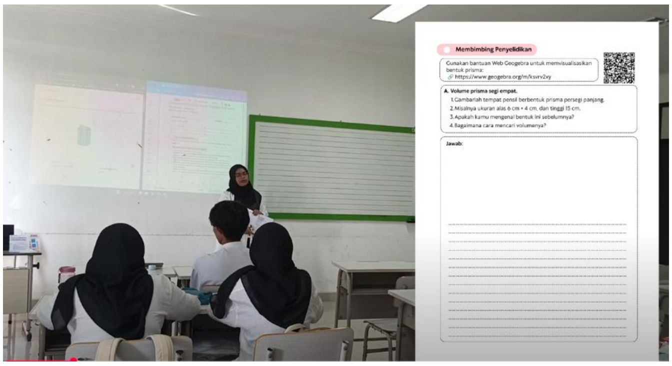

Figure 4. Documentation of Implementation of Technology-Enhanced Learning

Conversely, the 33% of PMTs who did not utilize technology experienced less than optimal teaching. For example, PMT MI attempted to illustrate a circle by drawing freehand on a whiteboard without standard tools. The resulting inaccurate visual representation compromised the definition of the circle, demonstrating how the lack of appropriate technology-enhanced tools can impede the teaching of abstract mathematical definitions. This confirms that basic teaching competence is insufficient without effective technology integration (Botzakis, 2017). This is illustrated in the following figure:

Figure 5. Documentation of Suboptimal Technology Implementation

Figure 5 shows PMT MI attempting to illustrate a circle on the whiteboard without standard tools (e.g., a compass). The resulting visual representation was inaccurate, featuring differences in the distance of several points from the center. This deficiency in utilizing a technology-enhanced tool compromised the precise geometric definition required for mathematical instruction.

CONCLUSION

Based on the criteria-based analysis, PMTs demonstrated adequate competence in integrating inductive learning and differentiated instruction (achieving the required 71% threshold for 6 out of 7 elements). The high success rates confirm that the microteaching curriculum effectively prepares prospective teachers to manage the structure of discovery learning and accommodate student heterogeneity. However, the study confirms a significant vulnerability in the cohort: competence in implementing technology-enhanced learning remains inconsistent, achieved by only 67% of PMTs. This indicates that while the foundations of instructional design are sound, the effective integration of digital tools for teaching complex mathematics remains an area needing focused development.

This study has several limitations. First, the small sample size ($N = 15$) limits the generalizability of the findings. Second, the data were collected during *peer teaching* (simulated classroom environment), which may not fully reflect the complexities, classroom management issues, or pedagogical depth required in an actual classroom setting. Finally, the analysis focused on observable implementation and did not measure the resulting learning outcomes of the hypothetical students.

Based on these findings, we offer specific recommendations for mathematics teacher education curricula to enhance PMTs' readiness. Firstly, training must strengthen Technology Integration by moving beyond passive hardware use and requiring mandatory, criteria-based practice using specialized mathematics software (e.g., GeoGebra, Desmos) to facilitate genuine conceptual exploration and visualization. Secondly, teacher educators should focus on the Depth of Differentiation by explicitly addressing advanced and structural differentiation strategies (e.g., product differentiation, choice in assessment) to ensure PMTs move beyond superficial adjustments and effectively manage the heterogeneity inherent in inductive learning designs. Finally, future research should utilize a longitudinal design to track PMT competence in actual classroom settings and investigate the correlation between the quality of technology used and the resulting student learning outcomes.

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