



Improving elementary teachers' digital pedagogical competence through google classroom training: a one-group pretest-posttest study

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Article info	Abstract
Keywords: digital pedagogical competence, elementary school teachers, professional development, quasi-experimental design, social science	The digital transformation of education represents a significant social shift that requires elementary school teachers to develop strong digital pedagogical competence. As schools increasingly integrate learning management systems into instructional practice, teachers play a central role in shaping how technology influences classroom interaction and learning processes. This study aimed to examine whether Google Classroom training was associated with changes in elementary school teachers' digital pedagogical competence within the broader context of educational digital transformation. A quasi-experimental one-group pretest-posttest design was employed involving 30 teachers from a public elementary school in East Java, Indonesia. Data were collected using a validated Likert-scale questionnaire and analyzed using descriptive statistics, the Shapiro-Wilk normality test, a paired-samples t-test, and Cohen's d effect size. The results revealed a statistically significant increase in competence scores after the training ($p < .001$) with a very large effect size ($d = 2.60$), interpreted using Cohen's conventional criteria (0.20 = small, 0.50 = medium, 0.80 = large). The study suggests that structured and pedagogically grounded Google Classroom training was associated with substantial gains in teachers' self-reported digital competence. These findings provide preliminary empirical evidence that targeted professional development may support teachers' readiness for digital learning environments in elementary education; however, because the study did not include a control group, the observed changes cannot be fully attributed to the training alone.

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1. Introduction

The rapid integration of digital technology into education has transformed not only how students learn but also how teachers design, manage, and evaluate instruction. In elementary schools, where foundational knowledge and learning habits are established, the role of teachers becomes even more critical in navigating this digital shift. The expansion of digital learning platforms has created opportunities for more flexible, interactive, and student-centered instruction. However, technological availability alone does not automatically translate into effective pedagogical practice (Méndez et al., 2023). Many schools have adopted digital tools, yet their pedagogical integration often remains superficial. Teachers may use digital platforms solely to distribute assignments rather than to redesign learning experiences that enhance engagement, collaboration, and formative assessment (Tondeur et al., 2017). This gap between access and meaningful implementation highlights the importance of strengthening teachers' digital pedagogical competence (Darmawan & Darmawan, 2026; Mananghaya, 2026).

Digital pedagogical competence refers to teachers' ability to integrate technology into teaching practices in ways that align with pedagogical principles and learning objectives. It is not limited to technical proficiency but includes instructional design, classroom management in digital environments, assessment strategies, and reflective practice (Koehler & Mishra, 2009). Contemporary frameworks, such as the Technological Pedagogical Content Knowledge (TPACK) model, emphasize that effective technology integration requires integrating technological, pedagogical, and content knowledge (Chai et al., 2013). In elementary education, this integration must be tailored to the developmental characteristics of young learners, who require structured guidance, interactive engagement, and clear instructional scaffolding (Ertmer & Ottenbreit-L. Therefore, strengthening digital pedagogical competence among elementary school teachers is both a theoretical and practical necessity.

One widely used digital platform in schools is Google Classroom, a cloud-based learning management system that enables teachers to distribute materials, manage assignments, provide feedback, and facilitate communication. Its interface is relatively simple and accessible, making it attractive for elementary school contexts (Dabbagh & Fake, 2019). Despite its accessibility, effective utilization of Google Classroom requires more than familiarity with its features (Pozo-Rico, 2020b). Teachers must understand how to design digital tasks that promote higher-order thinking, organize virtual classrooms efficiently, monitor student progress, and integrate multimedia resources strategically. Without structured training, teachers may underutilize the platform's pedagogical potential.

Previous studies have indicated that professional development programs may be associated with changes in teachers' digital competence and self-efficacy in using educational technology. Research has shown that targeted training has been linked to greater confidence and increased frequency of technology use, as well as to the adoption of more innovative instructional strategies (Darling-H. However, several gaps remain in the literature. First, many studies focus on secondary education or higher education contexts, while research specifically addressing elementary school teachers is comparatively limited (Febrianti & Putriyanti, 2026; Noviana & Fajar, 2026; Romero-Tena et al., 2020; Zain, 2026). Second, a considerable number of studies rely solely on descriptive or correlational approaches, measuring perceptions without implementing structured interventions (Fernandez-Rio, 2020). Third, limited research employs pretest–posttest designs to examine quantifiable changes in teachers' competence before and after training. As a

result, empirical evidence regarding the association between structured Google Classroom training and elementary school teachers' digital pedagogical competence remains insufficient.

From a practical perspective, elementary school teachers often face unique challenges in implementing digital learning. Younger students require clear instructions, close supervision, and simplified digital navigation. Teachers must balance curriculum objectives with age-appropriate technological integration. Furthermore, disparities in teachers' digital literacy can lead to uneven implementation within the same school (Pratiwi, 2023). Some teachers adapt quickly to digital platforms, while others struggle with basic features. This variation may lead to inconsistent learning experiences for students. Structured and systematic training programs are therefore essential to ensure that all teachers possess a minimum standard of digital pedagogical competence.

The present study addresses these theoretical and practical concerns by implementing a structured Google Classroom training program for elementary school teachers in one public elementary school in East Java, Indonesia. The training was designed not merely to introduce platform features but to connect those features with pedagogical strategies, classroom management techniques, and assessment practices suitable for elementary learners. Using a one-group pretest–posttest design, this study examines changes in teachers' self-reported digital pedagogical competence before and after the intervention (Omeh et al., 2022). This design enables an examination of score differences over time, although it does not permit attributing those differences solely to the training.

Maintaining a balance between theoretical and applied aspects, this research contributes to the ongoing discourse on technology integration by providing empirical evidence grounded in real classroom contexts. Theoretically, it extends discussions on digital pedagogical competence within elementary education by testing whether structured professional development can significantly enhance teachers' competence (Tulak et al., 2026). Practically, the findings may inform school leaders and policymakers about the effectiveness of targeted training programs in strengthening teachers' readiness for digital learning environments.

This study offers three contributions that distinguish it from existing literature. First, it focuses specifically on in-service elementary school teachers in Indonesia, a population that has received limited attention in the growing body of research on digital teacher competence. Most prior studies have examined secondary or tertiary-level educators, leaving the particular needs of elementary teachers who must balance technological integration with developmental appropriateness underexplored. Second, the intervention is pedagogically grounded rather than technically oriented: it explicitly links Google Classroom features to instructional design, classroom management, and assessment strategies through the lens of the TPACK framework. Third, the study employs a quantitative pretest-posttest design to measure changes in self-reported competence, moving beyond descriptive or perception-only studies that dominate this area. By situating the intervention within an Indonesian elementary school context and measuring change through a validated instrument, this study provides preliminary empirical evidence regarding the potential of targeted professional development to support teachers' readiness for digital learning environments.

Based on the background described above, this study aims to examine the association between Google Classroom training and elementary school teachers' digital pedagogical competence within the broader framework of educational digital transformation (Bamrungsin & Khampirat, 2022). Specifically, the research seeks to determine whether there is a significant difference in teachers' self-reported competence before and after participating in a structured training program. From a social science perspective, this inquiry does not merely assess

technical skill development but also investigates how professional development can serve as a potential mechanism for institutional adaptation to technological shifts.

2. Method

This study employed a quantitative, quasi-experimental design with a one-group pretest-posttest format. The design was selected to examine measurable changes in teachers' self-reported digital pedagogical competence before and after a structured training intervention. Because the study did not include a control group, causal attribution of observed changes to the training alone is not possible; rather, the design permits examination of score differences over time and assessment of their magnitude.

2.1. Research context and participants

The study was conducted at a public elementary school in East Java, Indonesia. The school was selected through purposive sampling based on its active use of digital learning platforms and its school leadership's willingness to participate in the research. All 30 elementary school teachers who were actively teaching during the semester were invited to participate. A total sampling approach was used; therefore, no teachers were excluded. Participation was voluntary, and written informed consent was obtained from all participants prior to data collection. Participants were informed of their right to withdraw at any time without negative consequences. Table 1 presents the demographic and professional characteristics of the participants.

Table 1. Participant characteristics (N = 30)

Characteristic	Category	n	%
Gender	Male	8	26.7
	Female	22	73.3
Age (years)	25-34	9	30.0
	35-44	14	46.7
	45-54	7	23.3
Teaching experience (years)	1-5	6	20.0
	6-10	10	33.3
	11-15	9	30.0
	>15	5	16.7
Prior Google Classroom use	Never used	12	40.0
	Used occasionally (1-2 times/month)	14	46.7
	Used regularly (≥1 time/week)	4	13.3
Self-rated digital literacy	Low	10	33.3
	Moderate	16	53.3
	High	4	13.3

The majority of participants were female (73.3%), aged 35-44 years (46.7%), with 6-15 years of teaching experience (63.3%). Notably, 40.0% had never used Google Classroom prior to the study, and 33.3% rated their overall digital literacy as low. These characteristics suggest that the sample represented teachers with varying levels of prior digital experience, a pattern common in Indonesian public elementary schools where technology adoption remains uneven.

2.2. Research design

The research followed three main stages: pretest measurement, training intervention, and posttest measurement. At the beginning of the study, participants completed a pretest questionnaire designed to measure their baseline digital pedagogical competence. Following this initial measurement, teachers participated in a structured Google Classroom training program over two weeks. After completing the training sessions, participants completed the same questionnaire as a posttest to assess changes in competence. The interval between pretest and posttest was 14 days. The independent variable in this study was Google Classroom training, while the dependent variable was teachers' self-reported digital pedagogical competence.

2.3. Training intervention

The intervention consisted of a structured training program focused on the pedagogical use of Google Classroom as a digital learning platform. The training was conducted over four sessions within two weeks, with each session lasting approximately 120 minutes. All sessions were facilitated by the first author, who holds a master's degree in educational technology and has five years of experience conducting teacher professional development programs in Indonesian elementary schools. The relevant data are presented in Table 2.

Table 2. Training program structure

Session	Topic	Learning Activities	Duration	Output
1	Introduction to digital pedagogy and learning management systems	Lecture on TPACK framework; discussion of digital pedagogical competence indicators; overview of Google Classroom interface	120 min	Participants can navigate the Google Classroom dashboard and identify core features.
2	Technical operation of Google Classroom	Demonstration: creating classes, enrolling students, uploading materials, organizing assignments; guided practice with facilitator support	120 min	Each participant creates a demo class with at least 5 sample students and 2 assignments.
3	Designing digital learning activities	Workshop: aligning Google Classroom activities with elementary curriculum objectives; peer review of activity designs; simulation of student view	120 min	Participants design one complete week of digital learning activities for their subject.
4	Online assessment and digital feedback	Demonstration: creating quizzes, rubrics, and comment banks; practice in providing audio and written feedback; independent practice with facilitator observation	120 min	Participants create one formative assessment with a feedback mechanism and receive verification from the facilitator checklist.

The training approach combined direct instruction, demonstration, guided practice, and independent practice. Each participant used a personal laptop connected to the internet. The equipment and materials included laptops with updated web browsers (Google Chrome version

144 or later), a stable internet connection (minimum 10 Mbps), a projector for demonstrations, and official Google accounts for classroom creation and management.

Success criteria for each session were verified through facilitator observation checklists. Participants who did not meet the output criteria in Sessions 2-4 received an additional 30-minute remedial guidance before the next session.

2.4. Instrumentation

Data were collected using a structured questionnaire measuring digital pedagogical competence. The instrument was developed by the research team based on the TPACK framework (Koehler & Mishra, 2009) and existing digital competence indicators for teachers (Tondeur et al., 2017). Table 3 presents the instrument blueprint.

Table 3. Instrument blueprint

Indicator	Definition	Number of Items	Example Item	Theoretical Basis
Understanding of Google Classroom features	Knowledge of technical functions and navigation within the platform	5	"I can create and organize assignments using Google Classroom."	TK (Technological Knowledge) - Mishra & Koehler, 2006
Ability to design digital instructional activities	Skill in developing learning activities that integrate Google Classroom with curriculum objectives	6	"I can design interactive learning activities using Google Classroom that align with elementary curriculum standards."	TPACK - Chai et al., 2013
Ability to manage digital classrooms	Skill in organizing virtual learning environments and monitoring student participation	5	"I can effectively manage student participation and behavior in a Google Classroom environment."	PK (Pedagogical Knowledge) - Koehler & Mishra, 2009
Ability to develop online assessments	Skill in creating and implementing formative and summative digital assessments	5	"I can create online quizzes and rubrics within Google Classroom to assess student understanding."	TPACK - Tondeur et al., 2018
Self-confidence in implementing digital learning	Belief in one's capability to successfully conduct technology-integrated instruction	4	"I feel confident in my ability to solve technical problems that arise during digital lessons."	Self-efficacy - Ertmer & Ottenbreit-Leftwich, 2010
Total		25		

Each item used a five-point Likert scale ranging from 1 (strongly disagree) to 5 (strongly agree). The total score ranged from 25 to 125, with higher scores indicating greater self-reported digital pedagogical competence. Before data collection, the instrument was validated through expert judgment by two educational technology experts with at least 10 years of experience. Experts evaluated each item for content relevance, clarity, and alignment with the indicator definitions. Items rated below 3 on a 4-point relevance scale were revised or replaced.

Construct validity was tested using Pearson product-moment correlation on a pilot sample of 15 teachers from a different elementary school (not included in the main study). The pilot sample size of 15 was determined based on the minimum requirement of 5-10 participants per item for exploratory validation (Comrey & Lee, 1992). Items with correlation coefficients below the critical r-value of 0.514 at $\alpha = 0.05$ (two-tailed, $df = 13$) were revised. All 25 items exceeded

this threshold and were retained. Instrument reliability was assessed using Cronbach's Alpha on the pilot data, yielding a coefficient of 0.87, indicating high internal consistency.

2.5. Data analysis

Data analysis was conducted in several stages. First, descriptive statistics were calculated to determine the mean, standard deviation, minimum, and maximum of pretest and posttest scores. Second, the assumption of normality was tested using the Shapiro-Wilk test for the pretest, posttest, and difference scores (posttest minus pretest). Testing the normality of difference scores is essential for validating the use of parametric tests in paired designs (Field, 2018).

If the data were normally distributed, a paired-samples t-test was used to determine whether there was a statistically significant difference between pretest and posttest scores at the 0.05 significance level. The mean difference was reported with a 95% confidence interval (CI) to indicate the precision of the estimate. If the normality assumptions were violated, the Wilcoxon signed-rank test was used as a nonparametric alternative. To determine the magnitude of the training effect, Cohen's d_z for paired samples was calculated using the formula:

$$d_z = \frac{M_{diff}}{SD_{diff}}$$

Where M_{diff} is the mean of the difference scores (posttest minus pretest), and SD_{diff} is the standard deviation of the difference scores. This form of Cohen's d is recommended for one-group pretest-posttest designs because it accounts for the correlation between paired observations (Lakens, 2013). The 95% CI for Cohen's d_z was calculated using the noncentral t-distribution method.

Effect sizes were interpreted using Cohen's (1988) conventional criteria: small (0.20), medium (0.50), and large (0.80). Values substantially exceeding 0.80 were described as very large, following Sawilowsky (2009).

3. Results

The results of this study are presented to examine whether Google Classroom training was associated with changes in elementary school teachers' self-reported digital pedagogical competence. The analysis includes descriptive statistics, normality testing, hypothesis testing, and effect size calculation.

3.1. Descriptive statistics

Table 4 presents the descriptive statistics of teachers' digital pedagogical competence scores before and after the training intervention.

Table 4. Descriptive statistics of pretest and posttest scores

Test	N	Mean	Std. Deviation	Minimum	Maximum
Pretest	30	67.40	6.85	55	79
Posttest	30	82.73	5.92	71	92

The descriptive analysis reveals a clear upward shift in teachers' self-reported digital pedagogical competence following the Google Classroom training. Prior to the intervention, the

mean pretest score was 67.40 (SD = 6.85), with scores ranging from 55 to 79. These values indicate that participants initially demonstrated a moderate level of competence, with relatively wider score dispersion suggesting variability in teachers' initial digital readiness.

After completing the training program, the mean posttest score increased to 82.73 (SD = 5.92), with scores ranging from 71 to 92. The increase of 15.33 points in the mean score reflects a substantial improvement in overall self-reported competence. In addition, the reduction in standard deviation from 6.85 to 5.92 suggests that participants' competence levels became more homogeneous after the intervention (Ramadan et al., 2026). In other words, the training not only raised average competence scores but also reduced variability among teachers, indicating a more consistent level of self-reported digital pedagogical capability across participants.

The upward shift in minimum scores from 55 (pretest) to 71 (posttest) further demonstrates that even participants with initially lower competence experienced meaningful improvement. Similarly, the increase in maximum scores from 79 to 92 indicates that teachers with relatively higher initial competence also enhanced their self-reported skills through the training.

3.2. Normality test

Before conducting hypothesis testing, the normality assumption was examined using the Shapiro-Wilk test for pretest, posttest, and difference scores (posttest minus pretest), as shown in Table 5.

Table 5. Shapiro-wilk normality test

Variabel	Statistic	Sig. (p)
Pretest	0.962	.341
Posttest	0.971	.512
Difference scores	0.958	.287

The Shapiro-Wilk test was applied because the sample size was fewer than 50 participants, making it more suitable and sensitive for small samples (Field, 2018). As presented in Table 5, the Shapiro-Wilk statistic for the pretest score was 0.962 ($p = .341$), for the posttest score was 0.971 ($p = .512$), and for the difference scores was 0.958 ($p = .287$). Since all significance values exceeded the .05 threshold, the null hypothesis of normality cannot be rejected for any of the three distributions. These findings indicate that the data met the normality assumption required for parametric testing, including the critical assumption that difference scores are normally distributed. Consequently, a paired-samples t-test was deemed appropriate to analyze the difference between pretest and posttest scores.

3.3. Hypothesis testing

To determine whether the difference between pretest and posttest scores was statistically significant, a paired sample t-test was conducted. The results are presented in Table 6.

Table 6. Paired sample t-test results

Variable Comparison	Mean Difference	SD Difference	t-value	df	p	95% CI for Mean Difference
Pretest-Posttest	-15.33	5.89	-14.27	29	< .001	[-17.53, -13.13]

Note. CI = confidence interval. The negative mean difference indicates that posttest scores were higher than pretest scores.

The analysis revealed a mean difference of -15.33 ($SD = 5.89$) between pretest and posttest scores. The negative value reflects the calculation order (pretest minus posttest), indicating that posttest scores were substantially higher than pretest scores. The obtained t -value was -14.27 with 29 degrees of freedom, and the p -value was $< .001$.

Since the p -value is well below the .05 threshold, the null hypothesis that there is no difference between pretest and posttest scores is rejected. This result indicates that the increase in self-reported digital pedagogical competence scores after the training was statistically significant (Sidik & Puspitasari, 2026). However, because the study employed a one-group pretest-posttest design without a control group, this increase cannot be fully attributed to the training alone. Other factors, such as repeated exposure to the questionnaire, temporary motivation following the training, or social desirability bias, may have contributed to the observed change.

3.4. Effect size

To evaluate the practical significance of the training, Cohen's d_z was calculated for paired samples using the formula $d_z = M_{diff} / SD_{diff}$. The result is presented in Table 7.

Table 7. Effect Size (Cohen's d_z)

Effect Size (d_z)	95% CI	Interpretation
2.60	[2.02, 3.18]	Very large

The calculated Cohen's d_z was 2.60, with a 95% confidence interval of 2.02 to 3.18. According to Cohen's (1988) conventional criteria, an effect size of 0.20 is considered small, 0.50 moderate, and 0.80 large. Following Sawilowsky (2009), values exceeding 0.80 are considered very large. Therefore, a value of 2.60 represents a very large effect.

This result indicates that the observed increase in teachers' self-reported digital pedagogical competence scores after the Google Classroom training was not only statistically significant but also substantial in magnitude (Nirmala et al., 2026; Rosidah, 2026). In practical terms, the training was associated with a significant increase in self-reported competence. However, the very large effect size should be interpreted cautiously, given the absence of a control group and the reliance on self-reported data, which may be susceptible to response bias.

4. Discussion

The findings of this study indicate that Google Classroom training was associated with a substantial increase in elementary school teachers' self-reported digital pedagogical competence scores, as reflected in the large mean difference between pretest and posttest and the very large effect size (Gameil & Al-Abdullatif, 2023; García-Martín et al., 2023; Karim & Na, 2024). However, because the study employed a one-group pretest-posttest design without a control group, this observed increase cannot be attributed solely to the training intervention. The following discussion considers possible explanations for the observed change, situates the findings within existing literature, and addresses the limitations that constrain causal interpretation.

Structured professional development. The improvement in competence scores may be partly explained by the structured nature of the training program, which integrated technical mastery with pedagogical application. Many technology-based trainings fail because they focus

only on operational skills, such as where to click, how to upload, and how to assign tasks. In contrast, this intervention connected platform features with instructional design, assessment strategies, and classroom management principles appropriate for elementary learners (Demszky et al., 2023; Yustina et al., 2020). By linking technological tools with pedagogical reasoning, the training likely strengthened what educational theory describes as the intersection of technological and pedagogical knowledge. When teachers understand not only how a tool works but also why and when it should be used, meaningful competence development may occur (Kelley et al., 2020; Lestari et al., 2021; Maeng et al., 2020; Romero-Tena et al., 2020). However, without a control group receiving no training or an alternative form of training, it remains possible that similar improvements could have occurred through other forms of professional development or self-directed learning.

Enhanced self-efficacy. The increase in competence scores may also be associated with enhanced self-efficacy, rather than or in addition to actual skill acquisition. Structured training provides guided practice, feedback, and simulation opportunities, all of which reduce anxiety toward digital platforms. Teachers who initially perceive technology as complex or intimidating often experience a cognitive shift once they successfully manage classroom scenarios during training (Abraham et al., 2022; Fidan, 2023). Competence in digital pedagogy is not solely about skill acquisition; it also involves confidence in implementing technology in authentic classroom settings. The self-reported nature of the instrument means that the observed increase may partly reflect enhanced self-perception rather than objective behavioral change.

Repeated exposure to the instrument. Because the same questionnaire was administered twice within a 14-day interval, the observed increase may have been influenced by repeated testing effects. Participants may have become more familiar with the item wording, response scale, or expected competencies, leading to higher scores on the second administration, independent of actual learning. This possibility is particularly relevant given that the posttest was conducted immediately after the training concluded, when participants were highly engaged with the content.

Temporary motivation and social desirability bias. The posttest was administered immediately after the final training session, a timing that may have captured temporary motivation or enthusiasm rather than sustained competence. Teachers who had just completed an intensive training program may have been inclined to rate their competence more favorably due to recency effects or a desire to demonstrate improvement to researchers and school leadership. Social desirability bias, the tendency to respond in ways that portray oneself favorably, may have been amplified in this context because participants knew their responses were being evaluated by the same facilitators who conducted the training.

Leveling mechanism. The reduction in score variability observed in the descriptive results suggests that the training may have functioned as a leveling mechanism. Before the intervention, teachers demonstrated varying degrees of digital literacy. After the training, competence scores became more homogeneous (Alneyadi et al., 2023; Huang et al., 2020). This outcome indicates that structured, school-based professional development can reduce internal disparities in teachers' technological readiness. From an institutional perspective, this is significant because consistent teacher competence may lead to more equitable student learning experiences. However, the absence of longitudinal data means it is unclear whether this homogeneity persisted over time or whether initially high-performing teachers maintained their advantage.

The very large effect size ($d \sim z = 2.60$, 95% CI [1.84, 3.35]) warrants cautious interpretation. In educational research, statistically significant findings with small practical effects are common; very large effects are rare and may signal methodological artifacts rather than genuine

educational impact (Chen et al., 2020; de Carvalho et al., 2021). Several factors may have inflated the observed effect size:

- a) Self-report bias: The reliance on self-reported questionnaire data rather than observational or performance-based measures may have produced larger effects than would be observed in actual classroom behavior.
- b) Immediate posttest timing: The absence of a delayed posttest means that the effect size captures immediate reactions rather than sustained learning.
- c) Single-school context: The homogeneity of the sample (all teachers from one school with similar institutional support) may have reduced error variance, artificially inflating the standardized effect size.

Replication across different schools and regions, with comparative control groups and observational measures, would be necessary to determine whether this effect size represents a robust educational impact or a context-specific artifact (Copur-Gencturk et al., 2024; Ebadi & Ebadijalal, 2020; Hackett et al., 2023).

Despite the limitations in causal attribution, the findings suggest that structured Google Classroom training may serve as a promising model for enhancing digital pedagogical competence in similar elementary school contexts. Schools facing challenges in digital integration may benefit from adopting systematic, practice-oriented training rather than relying on informal self-learning (Leoste et al., 2022; Shatri & Shala, 2022; Tai & Chen, 2022). The results imply that when professional development is carefully designed, even teachers with initially moderate self-reported competence can achieve substantial score improvements.

To strengthen practical impact, schools should consider:

- a) Post-training mentoring: Follow-up support to help teachers transfer training content to actual classroom practice.
- b) Classroom implementation observation: Direct observation of technology-integrated lessons to verify that self-reported competence translates into pedagogical behavior.
- c) Evaluation of student outcomes: Assessment of whether teacher competence gains are associated with improved student engagement or achievement.

Without these additional steps, improvements in self-reported competence remain a necessary but insufficient indicator of educational quality (Sumarmi et al., 2021). Beyond the immediate context, the findings contribute to broader discussions about digital transformation in education. Technology integration in elementary schools often encounters skepticism, particularly regarding young learners' readiness for digital environments. This study suggests that teacher readiness may be the more critical variable. When teachers possess strong digital pedagogical competence or at least perceive that they do, technology becomes a tool for enhancing instruction rather than a distraction. However, this conclusion is tempered by the recognition that perceived competence, as measured in this study, does not guarantee effective classroom implementation.

5. Conclusion and implications

This study found that structured Google Classroom training was associated with a statistically significant increase in elementary school teachers' self-reported digital pedagogical competence scores, with a very large effect size ($d \sim z \sim 2.60$, 95% CI [1.84, 3.35]). These findings suggest that targeted professional development may enhance teachers' perceived readiness to integrate digital platforms into pedagogically sound instructional practices. However, because

the study employed a one-group pretest-posttest design without a control group, relied on self-reported data, and administered the posttest immediately after training, the observed increase cannot be fully attributed to the training alone, nor can it be interpreted as evidence of sustained or actual classroom implementation.

The improvement occurred not merely at the technical level but also at the levels of instructional design, classroom management, and assessment within digital environments, as reflected in the self-reported scores. These preliminary results contribute to the scientific discourse on digital pedagogy by providing empirical evidence that competence development among elementary school teachers, as measured by self-report, can be associated with contextualized and practice-oriented training. From a practical standpoint, the study implies that schools and educational policymakers may consider systematic digital professional development programs as one component of broader strategies to support teachers' readiness for digital learning environments rather than relying solely on informal technological adaptation. Theoretically, the findings reinforce the importance of integrating technological and pedagogical dimensions within teacher development frameworks, particularly in elementary education contexts where instructional guidance and structure are critical.

Recommendations for Practice. To maximize the potential benefits of digital training programs, school leaders and policymakers are encouraged to complement initial training with sustained mentoring that supports teachers in translating self-reported competence into actual classroom practice. Direct observation of technology-integrated lessons should be conducted to verify that perceived competence gains are reflected in pedagogical behavior. Follow-up assessments administered several weeks or months after training would help distinguish temporary enthusiasm from sustained competence development. Ultimately, the value of teacher competence development lies in its impact on student engagement and achievement; therefore, student-level outcomes should be evaluated alongside teacher training programs.

Recommendations for Future Research. Future studies should address the limitations of this research by employing control group designs, such as a waitlist control or an alternative intervention, to strengthen causal inference. Observational or performance-based measures of digital pedagogical competence should be used to supplement self-report data. Longitudinal designs with multiple posttest waves would help examine the durability of competence gains. Finally, larger and more diverse samples across multiple schools and regions are needed to enhance generalisability.

6. Limitation

This study has several limitations that constrain the interpretation of the findings. First, the research was conducted at a single elementary school with a relatively small sample of 30 teachers, limiting generalisability to broader educational contexts. Second, the one-group pretest-posttest design without a control group restricts causal attribution: external factors such as independent practice, peer discussion, repeated exposure to the questionnaire, temporary motivation, or social desirability bias may have contributed to the observed score increase. Third, the reliance on self-reported data collected immediately after training, when enthusiasm was high, and the facilitator was present, means the findings reflect perceived rather than actual classroom competence. Fourth, the short-term measurement cannot establish whether the very large effect size represents durable learning or immediate enthusiasm. Finally, the facilitator was also the lead researcher, which may have introduced observer bias in participants' responses.

These limitations directly constrain the conclusions drawn throughout this manuscript. The observed increase in self-reported competence scores is best interpreted as preliminary evidence of an association between structured training and perceived competence, rather than definitive proof of causal effectiveness. Future research employing larger samples, control groups, observational measures, and longitudinal designs is needed to strengthen the robustness and applicability of these findings.

Declaration and Statement

CRedit Authorship Contribution Statement

Guntur Arie Wibowo conceptualized the study, developed the methodology, performed formal analysis, curated data, administered the project, and wrote the original draft. Bayu Tri Ambarsari and Mufti Riyani contributed to the investigation and data collection. Aulia Rahman contributed to methodology and validation. Sourav Choudhury contributed to validation, supervision, and manuscript review. All authors participated in writing, review, and editing, read the final manuscript, and agree to be accountable for all aspects of the work.

Declaration of Competing Interest

The author declares that there are no known competing financial interests or personal relationships that could have influenced the work reported in this paper.

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Data Availability Statement

The data that support the findings of this study are available from the corresponding author upon reasonable request. Because the dataset contains information about human participants, it is not publicly available to protect their privacy and confidentiality.

Ethical Declaration

This study involved human participants and was conducted in accordance with established ethical research standards. All procedures performed in this research adhered to the principles of the Declaration of Helsinki. Prior to data collection, all participants were informed of the study's purpose, research procedures, potential benefits, and their right to withdraw from participation at any time without negative consequences. Written informed consent was obtained from all participants before they participated in the study. Participant confidentiality and data privacy were strictly maintained throughout the research process.

Informed Consent Statement

The authors did not provide information regarding informed consent.

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Declaration of Generative AI and AI-Assisted Technologies

Portions of this manuscript were edited using Grammarly to improve grammar, language clarity, and overall readability. The author carefully reviewed and revised all suggested edits to ensure accuracy, coherence, and consistency with the intended meaning. The author takes full responsibility for the final content of the manuscript.

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