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TECHNOLOGICAL PEDAGOGICAL AND CONTENT KNOWLEDGE (TPACK)-BASED LEARNING TO IMPROVE TEACHERS' DIFFERENTIATED INSTRUCTION SKILLS

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ABSTRACT

This study aims to improve teachers' differentiated instruction skills through Technological Pedagogical and Content Knowledge (TPACK) learning at SMA Negeri 5 Tambusai Utara (Public's Junior high school 5 Tambusai Utara). The research method is quantitative with a pre-experimental design. The research design used is the Pretest Post-test Control Group Design, conducted on two groups of teachers with a total sample of 25 teachers. The sample was divided into two groups: the experimental group, which received full TPACK instruction, and the control group, which focused on strengthening Technological Knowledge (TK) and Content Knowledge (CK). Data collection was carried out through tests measuring teachers' differentiated teaching skills after TPACK learning. Data analysis used inferential methods assisted by SPSS 25 to test the research hypothesis. The hypothesis test results showed a significant difference in the improvement of differentiated instruction skills in the experimental group compared to the control group. Additionally, the results indicated that teachers in the experimental group were more active in designing, implementing, and evaluating differentiated instruction supported by appropriate technology and pedagogical strategies. In conclusion, TPACK training is effective in enhancing teachers' skills in applying differentiated instruction, supporting the implementation of the Merdeka Curriculum, and promoting the integration of technology in teaching.

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1. INTRODUCTION

A professional individual is one who possesses the appropriate competencies. It is not possible to work professionally by fulfilling only one of the required competencies (Fathurrahman, 2015; Agustin, D., & Prabowo, H., 2023). Similarly, a teacher is entitled to perform their duties only after acquiring the teaching competencies mandated by the government (Suhartono, E., & Widiya, N., 2022), as stipulated in the Teachers and Lecturers Law, Article 8 of the Republic of Indonesia Law Number 14 of 2005. A teacher is required to have at least four competencies: pedagogical, personal, social, and professional.

In developing their skills, teachers encounter numerous challenges and obstacles both within and outside the classroom environment. Therefore, teachers require support and guidance from their superiors to seek appropriate solutions. This is consistent with Glickman's objective in providing academic guidance as cited by Fasarahman, which emphasizes learning as a means to assist teachers in enhancing their teaching skills to achieve predetermined learning objectives for students.

One significant challenge faced by teachers in the instructional process is addressing the diverse characteristics of students, including differences in skills, experience, talents, interests, and learning styles. This diversity is encapsulated in the concept of differentiated instruction, a student-centered learning approach. Differentiated instruction serves as an extension and emphasis of student-centered learning within the Merdeka Curriculum, which recognizes the uniqueness of each student. Curriculum reforms are driven by changes in the era, lifestyle, and the evolving needs of learners. Teachers must adapt accordingly, keeping pace with technological advancements and knowledge developments in alignment with curricular changes.

Given the current demand for students to possess high levels of creativity, unrestricted by time and space, there is an accelerated need for information technology. Students are required to develop skills in searching, analyzing, synthesizing, transforming, deconstructing, creating, internalizing, and applying knowledge to themselves and their environment, as well as sharing it with peers.

In the domain of technical competencies, where assistance systems and skill recognitions are based on observation, comprehension, guided learning, communication methods, and knowledge transfer, the Merdeka Curriculum aims to cultivate students with advanced skills. Since the implementation of the Merdeka Curriculum, learning approaches capable of meeting these demands have become imperative. Among them is TPACK, an instructional framework that integrates technology and specific content applications in teaching. It encompasses seven interrelated knowledge domains. Marlina, Erlinda, & Sumarni (2021) assert that "TPACK training aids teachers in integrating technology use, instructional methods, and content materials, thereby enhancing learning quality."

The seven domains of TPACK include:

1. Content Knowledge (CK) – mastery of subject matter or instructional content, exemplified here by expertise in diesel common rail technology;
2. Pedagogical Knowledge (PK) – understanding of teaching processes and strategies that optimally foster student creativity and achievement of learning objectives;
3. Technological Knowledge (TK) – proficiency in utilizing digital technologies;
4. Pedagogical Content Knowledge (PCK) – integration of subject matter expertise with pedagogical strategies;
5. Technological Content Knowledge (TCK) – knowledge of digital technology applied to subject matter;
6. Technological Pedagogical Knowledge (TPK) – understanding of technology in conjunction with teaching methods and strategies;
7. Technological Pedagogical Content Knowledge (TPCK) – comprehensive integration of technological, pedagogical, and content knowledge.

The Merdeka Curriculum grants teachers autonomy in designing instructional strategies that align with students' needs and potentials. Within this framework, differentiated instruction is essential to accommodate student diversity in abilities, interests, and learning preferences. Effective implementation of differentiated instruction necessitates a profound understanding of TPACK, a framework that synergizes pedagogical, content, and technological knowledge.

2. METHODS

This study employed a quantitative approach with a pretest-posttest control group design. The research subjects consisted of 25 teachers, divided into two groups: the experimental group and the control group. The experimental group received TPACK training, while the control group received reinforcement of material and technology separately. Data collection instruments included differentiated teaching skills observation sheets and interviews. Figure 3 illustrates the research design.

O_1	X	O_2
O_3		O_4

Figure 1. Research Design Diagram (Fraenkel et al., 2011)

Note:

O_1 : Pretest for Experimental Group
O_3 : Pretest for Control Group
X : Treatment of TPACK-Based Learning (TPACK Training)
O_2 : Post-test for Experimental Group
O_4 : Post-test for Control Group

The rubric for assessing teachers' differentiated instruction can be used to evaluate the quality of teachers' portfolios based on several key aspects, such as lesson planning, lesson implementation, use of technology, as well as reflection and professional development.

Table 1. Rubric for Assessing Teachers' Differentiated Instruction

Aspect	Assessment Criteria	Score 1 (Poor)	Score 2 (Fair)	Score 3 (Good)	Score 4 (Excellent)
1. Lesson Planning	Quality and completeness of lesson plans included in the portfolio, covering objectives, strategies, media, and evaluation aligned with taught competencies.	Lesson plan is incomplete, unclear, and does not align with the competencies taught.	Lesson plan is fairly complete but not fully relevant to competencies and lacks key components.	Lesson plan is complete, aligns with competencies, and covers all main components.	Lesson plan is very complete, creative, innovative, relevant, and covers all components thoroughly.
2. Lesson Implementation	Alignment between lesson plans and classroom implementation, including the use of effective and interactive methods.	Implementation does not follow the plan, lacks interactivity, and uses ineffective methods.	Mostly follows the plan, somewhat interactive, but methods used are not optimal.	Follows the plan, is interactive, and uses effective methods.	Fully follows the plan, highly interactive, and uses very effective methods.

3. Use of Technology (TPACK)	Ability to integrate technology into the learning process according to the TPACK framework.	No technology use, or technology used is irrelevant to learning objectives.	Technology use is limited and sometimes irrelevant to learning objectives.	Technology use is relevant and aids the learning process.	Technology use is innovative, relevant, and significantly supports the learning process.
4. Differentiated Instruction	Ability to tailor instruction to meet the needs and potentials of diverse students (differentiated instruction).	No efforts to differentiate; all students receive the same instruction regardless of needs.	Some differentiation attempts, but not effectively meeting diverse student needs.	Differentiated instruction is adequately applied to meet most students' needs.	Differentiated instruction is excellently applied and effectively meets all students' needs using varied strategies.
5. Assessment and Evaluation	Completeness and clarity of assessment methods used to measure student competency achievement, including rubrics and other evaluation tools.	Assessments are unclear, irrelevant to objectives, and lack adequate rubrics or tools.	Assessments are somewhat relevant but incomplete; rubrics or tools are unclear.	Assessments are relevant, cover most competencies, with sufficiently clear rubrics and tools.	Assessments are highly relevant, cover all competencies, with clear and comprehensive rubrics and tools.
6. Reflection on Learning	Depth of reflection on teaching practice, including analysis of successes, challenges, and plans for improvement.	No or very minimal reflection, lacking in-depth analysis or improvement plans.	Reflection covers some aspects, but improvement plans are unclear.	Reflection is fairly deep, covering successes, challenges, and good improvement plans.	Reflection is very thorough, detailing successes, challenges, and comprehensive improvement plans.
7. Professional Development	Participation in professional development activities such as training, seminars, or collaboration with peers, and implementati	No evidence of participation or implementation of professional development.	Limited participation, with suboptimal implementation of outcomes.	Active participation, with fairly good implementation of outcomes.	Very active participation, with excellent implementation improving teaching quality.

	on outcomes teaching.	of in

Scoring Scale:

- 1 (Poor): Portfolio provides very minimal or irrelevant evidence for the assessed aspect.
- 2 (Fair): Portfolio provides adequate evidence but does not cover all assessed aspects.
- 3 (Good): Portfolio provides sufficient evidence aligned with expected standards.
- 4 (Excellent): Portfolio provides very comprehensive, innovative, and exceeding evidence.

Data analysis was conducted using t-tests with the assistance of SPSS 25 software. Teacher observation sheet responses were converted into Likert scale scores and subsequently analyzed using N-Gain to measure differences.

$$< g >= \frac{(S_f - S_i)}{(S_{maks} - S_i)}$$

Explanation:
Sf = mean post-test score
Si = mean pre-test score

The following table presents the interpretation of the N-Gain (Normalized Gain) values, which are commonly used to measure the improvement in students' understanding or abilities after instruction:

Table 2. Interpretation of N-Gain Scores

N-Gain Range	**Category**
0.70 – 1.00	High
0.30 – 0.69	Moderate
0.00 – 0.29	Low

Source: Hake (1998)

Assumption Tests

Before conducting the t-test, several assumptions must be tested, namely normality and, if performing an independent two-sample t-test, homogeneity of variances.

Normality Test

The normality test is used to ensure that the data to be tested follow a normal distribution. In this study, the Shapiro-Wilk test is used for normality testing due to the small sample size ($n < 50$).

Steps for the normality test:

1. Formulate hypotheses:
   - H_0: The data are normally distributed.
   - H_1: The data are not normally distributed.
2. Determine the significance level α (commonly 0.05).
3. Calculate the Shapiro-Wilk test statistic.
4. Compare the p-value to the significance level:
   - If $p > \alpha$, the data are normally distributed (fail to reject H_0).
   - If $p \leq \alpha$, the data are not normally distributed (reject H_0).

Homogeneity of Variances Test (Levene's Test)

The homogeneity of variances test is conducted when using an independent two-sample t-test. This test ensures that the variances of the two groups being compared are similar. However, this test is not conducted if the data are not normally distributed. The most common method used is Levene's Test.

Steps for the homogeneity test:

1. Formulate hypotheses:
   - H_0: The variances of the two groups are equal (homogeneous).
   - H_1: The variances of the two groups are not equal (heterogeneous).
2. Determine the significance level α (commonly 0.05).
3. Calculate the Levene's Test statistic.
4. Compare the p-value to the significance level:
   - If $p > \alpha$, variances are homogeneous (fail to reject H_0).
   - If $p \leq \alpha$, variances are not homogeneous (reject H_0).

Paired Sample t-Test

The paired sample t-test is used to analyze the significance of improvement in differentiated teaching skills of teachers before and after the intervention. This test is a follow-up hypothesis test if the data are normally distributed. The hypotheses in this study are:

- H_0: There is no significant difference in the improvement of differentiated teaching skills between the experimental and control groups of teachers at SMAN 5 Tambusai Utara after TPACK-based learning.
- H_1: There is a significant difference in the improvement of differentiated teaching skills between the experimental and control groups of teachers at SMAN 5 Tambusai Utara after TPACK-based learning.

After fulfilling the assumptions of normality and homogeneity of variances, parametric testing proceeds with the t-test. The steps include: determining the significance level (α), usually set at 0.05 or 5%, and calculating the two-sample independent t-test statistic using the following formula:

$$t = \frac{\bar{X}_1 - \bar{X}_2}{\sqrt{\frac{S_1^2}{n_1} + \frac{S_2^2}{n_2}}}$$

This test is a parametric test, meaning it is a hypothesis test conducted under the assumptions that the data are normally distributed and homogeneous. If the data do not meet these assumptions of normality or homogeneity, the subsequent hypothesis test applied is a non-parametric test, such as the Mann-Whitney U test.

3. FINDINGS AND DISCUSSION

The initial stage of the research was conducting a pretest or initial test on differentiated learning, with the data obtained as follows:

Table 3. Pretest Results – Experimental Class

No.	Experimental Class Code	Pretest Score
1	E1	16
2	E2	16
3	E3	16
4	E4	16
5	E5	16
6	E6	16
7	E7	16
8	E8	16
9	E9	16
10	E10	16

11	E11	16
12	E12	16

Table 4. Pretest Results – Control Class

No.	Control Class Code	Pretest Score
1	C1	16
2	C2	16
3	C3	16
4	C4	16
5	C5	24
6	C6	24
7	C7	24
8	C8	24
9	C9	24
10	C10	24
11	C11	24
12	C12	32
13	C13	32

In the experimental class pretest results, the scores were evenly distributed, reflecting similar abilities in differentiated learning. This occurred because the experimental group had not yet fully understood the concept of differentiated instruction. Meanwhile, the control group had more frequent exposure to differentiated learning through Merdeka Curriculum training and additional training in the Teacher Mobilization Program. However, 30.76% of the control group showed low pretest scores, likely because they were just beginning their participation in the Teacher Mobilization Education (CGP).

After implementing the treatment using TPACK-based learning, a posttest was conducted for both the experimental and control classes, with results as follows:

Table 5. Posttest Results – Experimental Class

No.	Experimental Class Code	Posttest Score
1	E1	30
2	E2	32
3	E3	29
4	E4	32
5	E5	32
6	E6	32
7	E7	29
8	E8	28
9	E9	32
10	E10	26
11	E11	32
12	E12	32

Table 6. Post-test Results – Control Class

No.	Control Class Code	Posttest Score
1	C1	28
2	C2	28
3	C3	32
4	C4	28
5	C5	32

6	C6	32
7	C7	32
8	C8	26
9	C9	28
10	C10	32
11	C11	30
12	C12	32
13	C13	32

The data in Tables 5 and 6 show an improvement in scores before and after the intervention. To measure the degree of improvement, the N-Gain scores were calculated as follows:

Table 7. N-Gain Results – Experimental Class

No.	Experimental Class Code	N-Gain Score	Category
1	E1	0.88	High
2	E2	1.00	High
3	E3	0.81	High
4	E4	1.00	High
5	E5	1.00	High
6	E6	1.00	High
7	E7	0.81	High
8	E8	0.75	High
9	E9	1.00	High
10	E10	0.63	Medium
11	E11	1.00	High
12	E12	1.00	High

Table 8. N-Gain Results – Control Class

No.	Control Class Code	N-Gain Score	Category
1	C1	0.75	High
2	C2	0.75	High
3	C3	1.00	High
4	C4	0.75	High
5	C5	1.00	High
6	C6	1.00	High
7	C7	1.00	High
8	C8	0.25	Low
9	C9	0.50	Medium
10	C10	1.00	High
11	C11	0.75	High
12	C12	0.00	Low
13	C13	0.00	Low

The average N-Gain for the experimental class was 0.91 (high category), while the control class had an average N-Gain of 0.67 (medium category).

After identifying the N-Gain scores, the next step was to analyze the significance of the improvement between the experimental and control classes by conducting prerequisite tests (normality and homogeneity tests) and further analysis (hypothesis testing).

Normality and Homogeneity Test

The normality and homogeneity tests are prerequisites to determine whether the data distribution is normal and homogeneous. In this study, statistical testing was performed using SPSS 25. The results of the normality test are as follows:

Table 9. Tests of Normality and Homogeneity

Group	Kolmogorov-Smirnov (K-S)	Shapiro-Wilk (S-W)
	Statistic	df
N-Gain Experimental	.349	12
N-Gain Control	.274	13

a. Lilliefors Significance Correction

Hypotheses Formulation:

- H_0: Data are normally distributed.
- H_1: Data are not normally distributed.

Set the significance level α (commonly 0.005). Compare the p-value to the significance level:

- If $p > \alpha$: Fail to reject H_0 (data are normally distributed).
- If $p \leq \alpha$: Reject H_0 (data are not normally distributed).

The condition to pass the normality test is if the Asymp. Sig. (2-tailed) value > 0.005. Based on Table 4.8, the experimental class has Asymp. Sig. (2-tailed) = 0.003 < 0.005, indicating $\mathbf{p \leq \alpha}$, so H_0 is rejected, and the data are not normally distributed. In the control class, the p-value is 0.008 > 0.005, so H_0 is not rejected — the data are normally distributed.

Since one of the classes (experimental) did not show a normal distribution, the homogeneity test was not conducted. Instead, a non-parametric test was used.

Hopotesis test

Parametric tests are used for hypothesis testing if both groups are normally distributed and homogeneous. However, if one of the datasets is not normally distributed, a non-parametric test, specifically the Mann-Whitney U Test, is applied. In this study, the Mann-Whitney U Test was used because the experimental group data were not normally distributed. The results of the hypothesis test are as follows:

Test Statistics[a]

	Ngain
Mann-Whitney U	25.500
Wilcoxon W	91.500
Z	-2.413
Asymp. Sig. (2-tailed)	.016
Exact Sig. [2*(1-tailed Sig.)]	.019[b]

a. Grouping Variable: Kelompok

b. Not corrected for ties.

The non-parametric paired sample test was used to analyze the significant differences in the improvement of teachers' differentiated learning skills before and after the intervention. This is a follow-up hypothesis test with the following hypotheses:

- $\mathbf{H_0}$: There is no significant difference in the improvement between the experimental and control groups in teachers' differentiated learning skills at SMAN 5 Tambusai Utara after the implementation of TPACK-based learning.

- **Ha**: There is a significant difference in the improvement between the experimental and control groups in teachers' differentiated learning skills at SMAN 5 Tambusai Utara after the implementation of TPACK-based learning.

The result of the hypothesis test showed a Sig or P-value of 0.0016 < 0.005. Since the p-value is less than the critical threshold of 0.005, this indicates a significant difference between the experimental and control groups. Therefore, H_0 is rejected, and Ha is accepted.

This research was conducted in the odd semester of the 2024/2025 academic year at SMAN 5 Tambusai Utara, Rokan Hulu Regency, Riau. The study involved 25 teacher participants divided into two groups: 12 teachers in the experimental group and 13 in the control group. Sample grouping was based on teachers' initial capabilities derived from a preliminary study. The experimental group consisted of teachers with relatively lower competence in teaching, selected to receive a full TPACK-based training intervention. The control group consisted of teachers with better initial competence, receiving only partial intervention. Most members of the control group were already "guru penggerak" (teacher leaders) accustomed to differentiated learning practices, making them suitable for comparison in measuring differentiated instruction skill improvement.

The intervention consisted of comprehensive TPACK-based training for the experimental group, focusing on strengthening their knowledge of PCK, CK, and TK, and integrating them into a full TPACK framework to support teachers' differentiated instruction skills.

The training included theory sessions, lesson planning practice, classroom visits, and direct teaching practice. Post-intervention observations showed that teachers became more enthusiastic and effectively implemented differentiated learning, including contextual teaching modules, adaptive instruction based on students' learning styles, and varied and relevant assessments.

The hypothesis testing results showed a significant improvement in differentiated instruction skills in the experimental group compared to the control group, supporting the acceptance of H_1. Teachers demonstrated better understanding in tailoring the learning process to students' needs. They used formative assessments to design instructional strategies and actively incorporated technology tools such as Quizziz, Padlet, and simple visual media to engage students.

Interviews revealed that 87.5% of teachers had a strong understanding of the Merdeka Curriculum, and all participants reported improved skills after the training. TPACK proved to be an effective framework for integrating teachers' knowledge of content, pedagogy, and technology. Observations also showed that teachers applied active learning models such as Problem-Based Learning (PBL), guided inquiry, project-based learning, and cooperative learning. They used varied assessments, including digital tools (Google Forms, Kahoot) and psychomotor assessments through reports and observations.

These findings indicate that TPACK-based training effectively enhances the quality of differentiated learning. The results align with theories by Marlina et al. (2021), Shulman (1986, 2004), and Niess (2009, 2022), who emphasize the importance of integrating pedagogical, content, and technological knowledge in developing teachers' professional competencies.

4. CONCLUSION

The conclusion should answer the objectives of the research and research discoveries. The concluding remark should not contain only the repetition of the results and discussions or abstract. You should also suggest future research and point out those that are underway. This study concludes that TPACK-based learning (*Technological Pedagogical Content Knowledge*) significantly enhances teachers' differentiated instruction skills at SMAN 5

Tambusai Utara. This is evidenced by the research data analysis, which shows that the alternative hypothesis is accepted—there is a significant improvement between the experimental and control groups following the implementation of TPACK-based training. Therefore, TPACK-based learning has proven effective in supporting teachers' ability to implement differentiated instruction, facilitating the implementation of the *Merdeka Curriculum*, and promoting the integration of technology into the teaching process. This research enriches the existing literature on the application of the TPACK framework in the context of differentiated learning and offers practical contributions to teacher professional development. The findings may serve as a foundation for future research in designing more relevant and effective technology-based learning models that are aligned with the needs of both teachers and students.

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