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The influence of the TPACK approach on IPAS learning outcomes at SDN 4 Bangunrejo

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Abstract

The low learning achievement of fifth-grade students in Natural and Social Sciences (IPAS) at SDN 4 Bangun Rejo indicates a problem in the learning process that is not optimal, especially in the pedagogical use of technology. This condition requires the implementation of a learning approach that is able to integrate technology, pedagogy, and content effectively. This study aims to analyze the effectiveness of the Technological Pedagogical Content Knowledge (TPACK) approach in improving elementary school students' science learning outcomes. The study used a quantitative approach with a One Group Pretest–Posttest design. The research subjects consisted of 30 fifth-grade students. The research instrument was a multiple-choice test that had met validity requirements, with 23 of 30 items declared valid, and had high reliability with a Cronbach's Alpha coefficient of 0.870. Data analysis was carried out through prerequisite tests in the form of normality and homogeneity tests, followed by a paired sample t-test. The results showed a significant increase in learning outcomes after the implementation of the TPACK approach. The average pretest score of 51.77 increased to 82.57 in the posttest. The paired t-test yielded a significance value of 0.000 ($p < 0.05$), indicating a significant difference between learning outcomes before and after treatment. These findings indicate that the TPACK approach is effective in improving conceptual understanding and the quality of science learning. This study concludes that the integration of technology, pedagogy, and content through the TPACK framework can be used as a sustainable learning strategy. The implications of this study emphasize the importance of improving teacher competency in implementing TPACK to support the development of 21st-century skills in elementary school students.

Keywords: *Students, Learning Outcomes, TPACK*

INTRODUCTION

The success of learning outcomes depends heavily on the educator's role as a facilitator in the learning process. The learning approach used has a significant impact on student learning outcomes. The right approach can help students understand the material, increase motivation, and create an active and enjoyable learning environment (Dogani, 2023; Afriani et al., 2025; Yustina Iyai & Yullys Helsa, 2025) . On the other hand, an inappropriate approach can hinder the learning process and make it difficult to improve learning outcomes (Nurlaili Hidayatul Baiti et al., 2024; Uptd et al., 2025; Dhea Divana Anggreni et al., 2025) . Based on the results of observations conducted with class V teachers at SDN 4 Bangun Rejo, several problems were found in science learning, namely: (1) differences in students' understanding of the teaching material, (2) less effective learning models, (3) low learning outcomes, and (4) lack of interest in learning.

Figure 1
Summative Outcome Values

The odd semester summative score table shows that the average student score was only 44, while the KKTP was set at 70. Of the 36 students, only one nearly reached the KKTP

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with a score of 69. Many students also had difficulty answering questions at the cognitive levels C1 (remembering) and C2 (understanding), indicating that their basic abilities were still low. This low achievement was caused by internal factors such as lack of focus, low motivation, and mismatched learning styles, as well as external factors such as an unsupportive environment, material complexity, and digital distractions (Gui & Akuba, 2024 ; Ilvi Sriwahyuni et al., 2024; Aisyah Fadhilah et al., 2025) Therefore, the implementation of a more effective and contextual learning approach is needed to improve student learning outcomes, especially in science subjects.

In this context, *the Technological Pedagogical and Content Knowledge* (TPACK) approach relevant to be applied to the learning process because it is able to integrate technology with pedagogy and teaching materials (Arifuddin et al., 2025; Filina et al., 2024; Saputro et al., 2025) TPACK is a learning method that combines 3 aspects, namely pedagogy, knowledge materials, and technology. (Denisa Alfaneanda Shafira, 2022) . TPACK is one of the most relevant learning approaches to 21st-century learning. TPACK is a framework used to teach material by integrating technology into learning that aims to meet the needs and interests of students which is expected to improve student learning outcomes (Widaningsih et al., 2023; Iriyani & Patty, 2025) . The TPACK model is a development of the Pedagogical Content Knowledge (PCK) model previously proposed by Shulman (1986). The Technological Knowledge (TK) element was then added by Pierson (2001) to complete the model, so it is known as TPCK as a framework for integrating technology into the learning process. Subsequently, Mishra and Koehler (2006) refined and reintroduced this model under the name TPACK (*Technological Pedagogical Content Knowledge*) to make it easier to understand and remember. Since its introduction, the TPACK model has continued to be used as the main theoretical framework in the development of technology-based learning models. (Rosmaladewi et al., 2023)

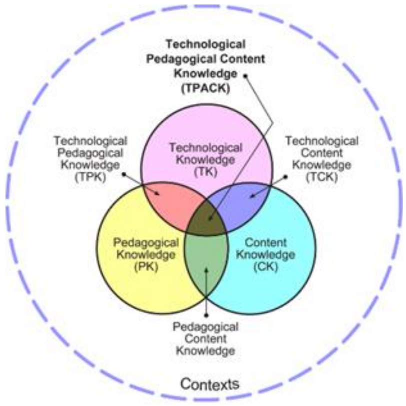

Figure 2
TPACK Framework Model

The image is a TPACK (Technological Pedagogical Content Knowledge) framework model that describes the relationship between three main components in teacher competence, namely:

1. Technological Knowledge (TK) — knowledge about method use and take advantage of technology . (Wardani, 2022)
2. Pedagogical Knowledge (PK) — knowledge of strategies, methods, and approaches in teaching (Dahlan, 2021).
3. Content Knowledge (CK) — in-depth knowledge of the material or content being taught.

These three components intersect and form new areas, namely:

- Pedagogical Content Knowledge (PCK): relationships between method teaching and content material .
- Technological Content Knowledge (TCK): relationships between technology and teaching materials .
- Technological Pedagogical Knowledge (TPK): relationships between technology and learning strategies (Ningsih et al., 2023) .

The intersection of these three components forms the central focus of what is known as TPACK, which is the teacher's ability to integrate technology, pedagogy, and content in a balanced manner in the learning process. This entire model exists within the context of the learning environment (contexts) that influence its implementation. Studies show that implementing a TPACK-based learning approach can significantly improve student understanding, engagement, and motivation (Ismail et al., 2023) . Through the application of TPACK, teachers are able to optimally integrate technology into the learning process to increase student engagement, creativity, and readiness to face the challenges of the rapidly evolving technological and digital era.

The TPACK approach is also highly relevant in science learning in elementary schools because it helps students understand abstract concepts through interactive and contextual media. (Lathifa et al., 2023) Technology integration allows teachers to present scientific phenomena through simulations, videos, or virtual experiments, making learning more engaging and meaningful. Thus, the application of TPACK not only improves science learning outcomes but also fosters critical and creative thinking skills, as well as the ability to adapt to technological advances (Nurdin et al., 2024) .

Educators who are able to implement the TPACK learning approach consistently and according to class needs will be able to foster curiosity and increase students' learning motivation in exploring learning materials (Nisa et al., 2024 ; Herwanto et al., 2024; Rosa et al., 2025); Although the TPACK approach is highly relevant to the demands of 21st-century learning, its implementation at the elementary education level still faces various obstacles, such as limited technological facilities and infrastructure and unequal internet access (Hasanuddin, Pesti, 2023) . In addition, variations in teacher competencies in integrating technology with pedagogical strategies also pose a challenge (Kumala, 2022) . The characteristics of elementary school students who are still at the concrete-operational thinking stage require adjustments to learning media to remain simple, interactive, and appropriate to their development (Filina & Sari, 2024 ; Hayat et al., 2024) Nevertheless, the TPACK approach has great potential to create more engaging and meaningful learning, while simultaneously developing 21st-century skills such as collaboration, communication, critical thinking, and student creativity (Fadjri et al., 2023). Therefore, strengthening teacher competencies through ongoing training, providing supporting resources, utilizing contextual technology, and supporting schools and parents is necessary to ensure optimal and sustainable implementation of TPACK in primary education (Nurillah et al., 2025) .

RESEARCH METHODS

This study used a quantitative approach with the aim of obtaining numerical data that was analyzed statistically to determine the effectiveness of implementing the TPACK approach in science learning (Fabian et al., 2024) . The research instruments consisted of learning outcome tests in the form of pretests and posttests, as well as documentation of grades and learning tools. These instruments were used to objectively measure changes in student learning outcomes before and after the implementation of the TPACK approach (Backfisch et al., 2024) .

Data collection was conducted using a quasi-experimental design using a One-Group Pretest–Posttest Only Design. This design was chosen because it allows researchers to identify differences in student abilities before and after treatment, even without a control group. This design is also commonly used in quantitative educational research when creating a comparison group is neither administratively nor ethically feasible.

The research procedure was implemented through three main stages. The first stage was a pretest to obtain quantitative data on students' initial abilities. The second stage was the provision of treatment in the form of TPACK-based learning that integrates aspects of technology, pedagogy, and content in a systematic and planned manner. The third stage was a posttest to collect data on student learning outcomes after the intervention was administered.

Data analysis was conducted quantitatively and sequentially. The initial stage of analysis included normality and homogeneity tests as statistical prerequisite tests. After the prerequisites were met, the data were analyzed using a paired sample t-test to determine the significance of the difference between pretest and posttest scores. Next, an N-Gain calculation was performed to determine the level of improvement in student learning outcomes classified into low, medium, or high categories. Through the application of a One-Group Pretest–Posttest Only design and systematic and objective statistical analysis, this study produced empirical findings that can be scientifically accounted for regarding the effectiveness of the TPACK approach in improving fifth-grade student learning outcomes in science learning.

RESULTS AND DISCUSSION

At the stage research, researcher moreover formerly carry out a series of instrument tests to ensure that device the test that will be used own adequate quality For measure ability participant educate in a way accurate . Validity testing was conducted on 30 multiple-choice items that had been compiled based on relevant competency indicators and cognitive levels. The validity testing process was carried out using SPSS version 26 software through item correlation analysis using the Corrected Item-Total Correlation technique. Based on the results of data processing, it was found that of the total 30 items analyzed, 23 items were declared to meet the validity criteria because they had a correlation value above the minimum limit set, namely r count > r table at a significance level of 0.05. Meanwhile, 7 other items were declared invalid so they were eliminated or revised so as not to reduce the overall quality of the instrument.

After the instrument was declared empirically valid, the researcher continued by conducting a reliability test using the Cronbach's Alpha technique which was also processed through SPSS 26. This reliability test aims to determine the level of internal consistency between test items in measuring the same construct. The results of the analysis showed that the Cronbach's Alpha coefficient value was in the high category, so that the remaining test instrument could be said to be reliable and suitable for use in the research data collection stage. Thus, the instrument that has gone through the validity and reliability testing process can provide assurance that the resulting data will be accurate, consistent, and able to describe students' abilities objectively.

Table 1
Reliability Test Results

Reliability Statistics	
Cronbach's Alpha	N of Items
0.870	30

Based on the reliability analysis results presented in Table 1, the Cronbach's Alpha coefficient value was 0.870. This value is well above the minimum limit of 0.60 as stated by Yusuf F. Zakariya (2022), who stated that an instrument can be categorized as reliable if the Cronbach's Alpha value exceeds this threshold. This finding indicates that the instrument has a very good level of internal consistency, so that each item in it works coherently in measuring the same construct. The reliability coefficient of 0.870 also indicates that the test instrument is in the high category, meaning that variations in student responses are caused more by differences in actual ability, rather than by instrument inaccuracy. In other words, this instrument is capable of producing stable and replicable data when used under similar conditions. A high level of reliability is crucial in educational research, as it ensures that the data obtained truly reflects student abilities and is not an artifact of an inconsistent instrument.

By considering the reliability value, it can be concluded that the test instrument used in this study is suitable for application in the data collection process related to improving the learning outcomes of fifth grade students. A reliable instrument provides a strong basis for further analysis, so that the research findings can be scientifically accounted for and provide a significant contribution to efforts to improve the quality of learning in elementary schools.

Table 2
Results of statistical description analysis

	Amount student	Minimum	Maximum	Mean		Standard Deviation
				Statistics	Std. Error	Statistics
Pre-test	30	33	70	51.77	1,683	9,216
Post-test	30	70	97	82.57	1,233	6,755
Valid N (listwise)	30					
Maximum score = 100						

Research data obtained from results pre-test and post-test of participants Students . Based on Table 2, before being given treatment, 30 students obtained pre-test scores ranging from 33 to 70, with an average of 51.77 and a standard deviation of 9.216. After implementing the TPACK learning approach, there was a significant increase in learning outcomes. Post-test scores showed an increase in the score range to 70 to 97, with an average of 82.57 and a standard deviation of 6.755. These findings indicate that the implementation of the TPACK learning approach provides a positive and effective contribution in improving student learning outcomes.

A normality test was conducted to ensure that the student learning outcome data from the pretest and posttest stages in *the One Group Pretest–Posttest design* were normally distributed. This normality test is a prerequisite before conducting further parametric analyses, such as homogeneity tests and *paired sample t-tests* . The results of the normality test for the research data are presented in the following table:

Table 3
Normality Test Results

	Kolmogorov-Smirnov [a]			Shapiro-Wilk		
	Statistics	df	Sig.	Statistics	Df	Sig.
Pretets Results	.153	30	.070	.939	30	.087
Posttest Results	.128	30	.200*	.963	30	.367

Using the Shapiro–Wilk test, the pretest significance value was 0.087 and the posttest significance value was 0.367. Both values were above the 0.05 significance level, indicating that the pretest and posttest data were normally distributed. Thus, the distribution of data before and after treatment met the normality assumption required for parametric analysis.

Table 4
Results of Homogeneity Test

		Levene Statistics	df1	df2	Sig.
Results	Based on Mean	3.104	1	58	.083
	Based on Median	2,275	1	58	.137
	Based on Median and with adjusted df	2,275	1	52,791	.137
	Based on trimmed mean	3,189	1	58	.079

Based on the results of *Levene's Test* in the *mean-based category* , a significance value of 0.083 was obtained. This value is higher than the significance limit of 0.05, so the variance between the pretest and posttest data is declared homogeneous. Thus, the homogeneity assumption is met and the data meets the requirements for further parametric analysis.

Table 5
Results of the Paired Sample T-test

Data Pair	Mean	Standard Deviation	Std. Error Mean	95% Confidence Interval of the Difference	t	df	Sig. (2-tailed)
Pretest – Posttest	-30,800	11,180	2,041	Lower: -34,975 Upper: -26,625	-15,089	29	0,000

Paired *Sample t-test* used For identify difference results Study participant educate before and after implementation approach TPACK learning . Based on *the Paired Samples Statistics* table , it is known that the average pretest score was 51.77, while the average posttest score increased to 82.57. The average difference of -30.800 with a standard deviation of 11.180 indicates a substantial increase after the treatment was given. The results of *the Paired Sample t-test* produced a t-count value of -15.089 with 29 degrees of freedom and a significance value of 0.000 ($p <0.05$).

This discussion focuses on improving student learning outcomes as measured by the N-Gain value, with categories of High (≥0.70), Medium (0.30–0.70), and Low (<0.30). What is the level of effectiveness of learning treatment based on the average N-Gain category obtained by students. Based on given table :

Table 6.
N-Gain Test Results

No	N-Gain Category	Average
1	≥ 0.7 (High)	0.629973
2	0.3–0.7 (Moderate)	
3	<0.3 (Low)	

The average N-Gain value available is 0.629973, which is in the range of 0.30–0.70, so it is included in the Moderate category. The average N-Gain value of 0.629973 indicates that the increase in student learning outcomes is in the Moderate category. This means that the learning treatment provides a fairly effective effect but has not yet reached a high level of effectiveness. Thus, the applied approach has been able to significantly improve student abilities, although there is still room for improvement to achieve more optimal improvements.

In addition to the overall effectiveness of the TPACK approach, further analysis reveals several anomalous findings related to individual learning gains. These anomalies highlight variations in students' responses to the intervention and provide a deeper understanding of the distribution of learning outcomes, as summarized in Table 7.

Table 7
Anomaly Data Analysis Results Study Student

No	Indicator Anomaly	Findings Based on Research Data	Interpretation Academic
1	Student with high pretest scores	A number of student own pretest scores are close limit top (±65–70)	Happen *ceiling effect* , so that room improvement score on the posttest it becomes limited
2	Improvement score No proportional	Although posttest scores increased , the difference score (gain) on student certain relatively small	Impact TPACK treatment does not uniform on all over individual
3	N-Gain not yet reach category tall	The average N- Gain is 0.629 on category moderate (0.30–0.70)	Show part student Not yet get improvement maximum
4	Variation readiness technology	No all student show the same adaptation towards media- based technology	Difference digital literacy influences effectiveness TPACK learning
5	Decline standard posttest deviation	SD decreased from 9,216 (pretest) to 6,755 (posttest)	Equality results Study increased , but student capable tall shows more gain small
6	Domination improvement on group certain	Improvement significant more Lots happen on student with ability beginning low – medium	TPACK approach is more impact on group the compared to student capable beginning tall

Table 7 illustrates that although the TPACK approach significantly improves learning outcomes at the class level, individual variations remain evident. These anomalous findings indicate that students with higher initial abilities tend to show smaller learning gains, while students with low to moderate prior knowledge benefit more substantially from the intervention. This condition suggests the need for differentiated instructional strategies within TPACK-based learning to accommodate diverse student characteristics.

These findings indicate that the implementation of the TPACK learning approach significantly improves student learning outcomes. This demonstrates that the integration of technology, pedagogy, and content in learning is effective in improving measured competencies and supporting optimal achievement of learning objectives.

The results of this study indicate that the application of the Technological Pedagogical and Content Knowledge (TPACK) learning approach significantly improved student learning outcomes in fifth-grade science. This improvement is evident in the difference in average pretest and posttest scores, from 51.77 to 82.57 after the treatment. This finding is supported by the results of a paired sample t-test, which showed a significance value of 0.000 ($p < 0.05$), indicating a statistically significant difference between the students' initial and final abilities. Therefore, the improvement in learning outcomes is not coincidental but a direct consequence of the implementation of the TPACK approach in the learning process.

Furthermore, the quality of the research instrument supports the validity of the findings. The validity test results showed that 23 out of 30 items were declared valid, while the reliability test yielded a coefficient of 0.870, which is above the minimum limit of 0.60. This confirms that the test instrument used has a high level of internal consistency and is suitable for use as a measurement tool for learning outcomes. The decrease in standard deviation values in the posttest also indicates that student learning outcomes became more equitable and stable after implementing the TPACK approach, reflecting the effectiveness of classical learning.

The findings of this study align with TPACK theory, which emphasizes the importance of integrating technological knowledge (TK), pedagogical knowledge (PK), and content knowledge (CK) in creating meaningful and contextual learning. These results reinforce previous research findings that TPACK-based learning can improve student conceptual understanding and learning outcomes, particularly in subjects that are conceptual in nature and require concrete visualization, such as science and science. The use of technology-based media, such as instructional videos, animations, and interactive simulations, has been shown to help students grasp abstract concepts more easily and engagingly, thus making the learning process more effective.

In terms of pedagogical implications, the results of this study indicate that the TPACK approach contributes to creating more interactive, learner-centered learning that aligns with the demands of 21st-century learning. Pedagogically designed technology integration encourages increased student motivation, active engagement, and independence in learning. For elementary school teachers, these findings provide important implications regarding the urgency of improving professional competency by integrating technology, pedagogy, and content in a balanced manner so that learning is not solely oriented toward achieving learning outcomes but also toward developing critical thinking skills, creativity, and technological literacy.

However, this study has several limitations that warrant consideration. The study was conducted in only one class with a relatively limited sample size, so the results cannot be broadly generalized. Furthermore, this study only examined learning outcomes in the cognitive domain, thus not providing a comprehensive picture of the impact of the TPACK approach on students' affective and psychomotor domains. The relatively short duration of the TPACK approach also limits the ability to observe the long-term impact of learning. Therefore, further research is recommended to involve a larger sample size, extend implementation time, and examine other variables to obtain a more comprehensive picture of the TPACK approach's effectiveness in science learning.

CONCLUSION

Based on the research findings that apply *the One Group Pretest–Posttest design* , it can be confirmed that the TPACK-based learning approach has a significant impact on improving students' learning outcomes in the fifth grade science subject. The increase in the average score from 51.77 in the pretest to 82.57 in the posttest indicates a substantial change in ability after students received learning interventions. The results of the prerequisite analysis test also indicate that the data from both test groups are normally distributed and have homogeneous variance, so that the inferential analysis procedure can be carried out validly.

A *paired sample t-test* with a significance value of 0.000 ($p < 0.05$) strengthens empirical evidence that there is a significant difference between students' initial and final abilities. This finding indicates that the integration of technology, pedagogy, and content aspects in the TPACK model can create a more meaningful, interactive, and relevant learning experience for students. Learning that utilizes technology appropriately, accompanied by pedagogical strategies aligned with the characteristics of the material, has been shown to significantly improve students' conceptual understanding and cognitive achievement.

Overall, this study confirms that the implementation of the TPACK approach is not only effective in improving learning outcomes but also has the potential to strengthen the quality of the science and science learning process in elementary schools. The practical implications of these findings suggest that teachers need to optimize the integration of technology into learning in a planned and structured manner, so that students' abilities develop according to the demands of 21st-century competencies. Thus, TPACK can be positioned as a relevant and strategic learning framework for improving the quality of education at the elementary school level.

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