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TPACK and Its Contribution to Develop Differentiated Learning in Elementary School

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Abstract

In recent years, the integration of technology in education has become increasingly vital for enhancing teaching and learning processes. This study utilized a correlational research methodology, focusing on elementary schools in the city of Yogyakarta that have adopted an independent curriculum. A sample of 20 teachers was selected using stratified random sampling. Data collection was conducted through questionnaires, with both questionnaire grids and sheets employed. The data analysis was performed using descriptive and inferential statistics. The research findings indicate positive values for various components of Technological Pedagogical Content Knowledge (TPACK): TPACK (0.894), Content Knowledge (CK) (0.783), Technological Knowledge (TK) (0.782), Pedagogical Knowledge (PK) (0.869), Pedagogical Content Knowledge (PCK) (0.835), Technological Content Knowledge (TCK) (0.866), and Technological Pedagogical Knowledge (TPK) (0.861). These results suggest that a teacher's TPACK significantly influences and is closely associated with their ability to develop differentiated learning strategies. These findings imply that professional development programs aimed at enhancing teachers' TPACK could play a crucial role in improving their effectiveness in implementing differentiated learning strategies.

INTRODUCTION

Background of the Study

The "Merdeka" curriculum is distinguished by its student-centered learning approach. Differentiated learning is employed to address the diverse needs of students through structured and targeted activities (Dalila et al., 2022; Sugiyanto et al., 2024). This approach is tailored to individual student needs, facilitating the selection, reception, management, and retention of information, all of which contribute to successful learning outcomes (Hasanah et al., 2022). By fostering inclusive education, differentiated learning provides equal opportunities for all students, thereby enhancing their self-confidence and motivation (Hasanah et al., 2023). Teachers cater to students' varied needs by offering a range of learning resources aligned with their unique characteristics, such as books, videos, and images (Khan et al., 2010; Ma et al., 2021).

Differentiated learning is comprised of four essential elements: content, process, product, and learning environment. It is implemented through a two-step process that includes analyzing students' levels of difficulty and varying lesson plans, alongside adapting or designing new learning strategies based on students' needs and interests (Papanthymou & Darra, 2022; Seghroucheni & Chekour, 2022). The teacher’s role in differentiated learning is pivotal, as educators must meet students' learning requirements by providing a variety of resources. Implementing differentiated learning demands that teachers possess expertise in Technological Pedagogical Content Knowledge (TPACK), a framework widely adopted by educational technologists and teacher educators to enhance the pedagogical use of Information and Communication Technologies (ICT) in classrooms. By incorporating TPACK into their teaching practices, educators can effectively tailor instruction to meet the diverse needs of students, adapt instructional designs to individual requirements, and optimize learning outcomes (Chai et al., 2013).

The integration of TPACK into teaching practices is vital for creating dynamic and effective learning environments. By synthesizing technological, pedagogical, and content knowledge, teachers can design engaging lessons, customize instruction to meet students' needs, and elevate the overall quality of education (Sari & Mega, 2022). TPACK not only empowers teachers to deliver impactful instruction but also equips students with the skills and knowledge required to thrive in a rapidly evolving educational landscape (Nuangchalerm, 2020). Through the application of TPACK, teachers can significantly enhance students' motivation, creativity, and overall learning outcomes (Nithitakkharanon et al., 2023).

Problem of The Study

This study examined the gap between the concept of an independent curriculum and teachers' readiness to develop differentiated learning. Although the independent curriculum is designed to enhance learning flexibility, it still requires significant adjustments and the overcoming of various obstacles. The implementation of the independent curriculum presents both substantive and technical challenges (Fitriyah & Wardani, 2022). Issues in learning arise not only from students but also from teachers who employ techniques that do not align with student characteristics (Melka & Jatta, 2022). Teachers often face limitations in available teaching materials, lack experience with independent curriculum concepts, and struggle to find relevant references due to a scarcity of resources (Denti et al., 2023; Subandi et al., 2024). As a result, they frequently resort to traditional, monotonous lecture-based methods.

Research’s State of the Art

The "Merdeka" curriculum integrates differentiated learning as a key approach designed to accommodate the unique characteristics of each student. This method addresses individual learning needs (Pitaloka & Arsanti, 2022), empowering students to develop their potential in alignment with their readiness and learning profiles (Sarie, 2022). By providing tailored learning experiences, differentiated learning fosters more meaningful and memorable educational opportunities (Tamrin, 2023). According to Suwartiningsih (2021), this approach nurtures diverse classroom environments by offering students multiple pathways to access content and process ideas, thereby enhancing educational outcomes. Similarly, Gusteti and Neviyarni (2022) highlight that differentiated learning allows students to engage with material according to their unique abilities and needs, reflecting educators' efforts to tailor classroom activities to students' readiness, interests, and learning profiles (Tezcan & Temel, 2023).

As a curriculum-based approach, differentiated learning prioritizes students' individual needs, granting them the autonomy to develop their potential according to their learning styles while promoting diversity within the classroom. It ensures equitable learning opportunities by enabling students to acquire and process content at their own pace and according to their abilities. Differentiated learning is characterized by its proactive nature, emphasis on quality over quantity, foundation in assessment, provision of varied instructional approaches, and learner-centered focus (Rahayu & Rosti, 2023; et al., 2024). Teachers must be attentive to the key elements of differentiated learning, integrating these differences to facilitate the gathering of information, the generation of ideas, and the effective communication of knowledge. This approach fosters a diverse classroom environment that promotes content mastery, enhances the processing of ideas, improves outcomes, and increases learning effectiveness. Moreover, differentiated learning requires teachers to adapt instructional topics to enrich students' learning experiences and improve retention (Ginja & Chen, 2020).

Gap Study & Objective

Differentiated learning consists of four essential components: content differentiation, process differentiation, product differentiation, and learning environment differentiation (Lmati, 2022; Maryani & Suyatno, 2023). Content differentiation refers to how teachers present instructional material in the classroom or how students engage with that material. Process differentiation involves the activities students engage in, designed to offer meaningful learning experiences rather than mere distractions. Product differentiation concerns the final outcomes of learning, showcasing students' knowledge, skills, and understanding through various outputs guided by the teacher. Finally, learning environment differentiation encompasses the individual, social, and physical structure of the classroom, tailored to students' readiness, interests, and learning styles, with the aim of fostering high motivation (Shatla, 2024).

Teachers who are proficient in Technological Pedagogical Content Knowledge (TPACK) are equipped to plan lessons using methods and strategies that effectively integrate technology. This competency is crucial for both current and aspiring elementary school teachers, who are required to teach across all subject areas. With TPACK, teachers can seamlessly plan and develop lessons that incorporate technology, aligning these with the instructional material and tailoring strategies to the unique characteristics of their students (Kale et al., 2020). Experts emphasize the pivotal role of TPACK in education, as it enables teachers to create effective and efficient learning experiences by integrating technology with pedagogical skills and content knowledge. Teachers with TPACK capabilities can design instructional tools that encompass all aspects of the framework: technological knowledge (TK), pedagogical knowledge (PK), content knowledge (CK), technological content knowledge (TCK), pedagogical content knowledge (PCK), technological pedagogical knowledge (TPK), and technological pedagogical content knowledge (TPACK) (Aktaş & Özmen, 2020; Deng et al., 2017).

Several theoretical frameworks will be employed to synthesize the indicators of TPACK, forming the basis for its measurement in this research. Content Knowledge (CK) refers to a teacher's understanding of the subjects they teach. Pedagogical Knowledge (PK) involves the teacher's ability to manage the classroom in alignment with students' characteristics. Technological Knowledge (TK) pertains to the teacher's understanding of technology and its potential applications in the learning process. Technological Content Knowledge (TCK) involves the teacher's ability to effectively deliver instructional material through the use of technology. Pedagogical Content Knowledge (PCK) refers to the teacher's skill in integrating content with appropriate instructional strategies. Technological Pedagogical Knowledge (TPK) reflects the teacher's proficiency in selecting and utilizing suitable technologies to support learning, tailored to students' individual needs.

By taking into account student characteristics, TPACK enables teachers to select and integrate technology that aligns with the learning content. Differentiated learning is closely aligned with TPACK, offering a framework that allows teachers to incorporate technology based on both learner characteristics and content (Dewi et al., 2024; Patalinghug & Arnado, 2021). Teachers who are proficient in TPACK can choose technology that meets students' needs and complements the learning materials, enabling students to learn at their own pace and in their preferred style, thereby fostering a more effective and enjoyable learning experience. Consequently, this research aims to investigate how teachers' TPACK competencies contribute to their ability to develop differentiated learning.

METHOD

Research Design

This study utilized a quantitative approach with a correlational design. The primary goal of correlational research is to assess the strength and nature of the relationship between variables, providing a comprehensive understanding of these connections (Simonton, 2024). In this research, the correlation between TPACK and teachers' abilities to develop differentiated learning strategies is examined.

Population and Sample

The research population comprises elementary school students in Yogyakarta. This focus on Yogyakarta enables an exploration of how effectively TPACK can enhance differentiated learning strategies tailored to the specific needs of the region's students. The study provides insights into how the integration of technology, pedagogy, and content knowledge can address the unique learning requirements of Yogyakarta's elementary students. Conducting the study in Yogyakarta allowed the researcher to gain a deep understanding of the local educational context and to evaluate the potential of TPACK to transform teaching practices and improve student outcomes in this specific setting. The practical application of TPACK in elementary school settings underscores its potential to revolutionize teaching through personalized and engaging instructional methods (Özdemir, 2016).

Yogyakarta has 151 public and private elementary schools that have implemented the Merdeka Curriculum, which includes three categories: Mandiri Belajar, Mandiri Berubah, and Mandiri Berbagi. These schools constitute the population for this study. In correlational research, a minimum sample size of 30 subjects is generally required to determine the existence of a correlation (Schweizer & Furley, 2016). Stratified random sampling was used as the sampling technique, ensuring adequate representation of each subgroup (Boschetti et al., 2016).

Data Collection Technique

The data collection in this study was conducted using a questionnaire-based approach. This method involved distributing a series of written questions or statements to respondents for them to answer. Two distinct sets of questionnaires were employed, each carefully designed to measure the variables of interest: Technological Pedagogical Content Knowledge (TPACK) and Teacher Skills in Developing Differentiated Learning (TSDDL).

The researcher utilized a closed-ended questionnaire, where respondents selected from predetermined options. Responses were captured on a 1 to 7 interval scale, with 1 representing "very incapable" and 7 representing "very capable." The questionnaire included both favorable (positive) and unfavorable (negative) statements. A semantic differential scale served as the measurement tool for both the TPACK and TSDDL variables. Tables 1 and 2 provide the blueprints for the TPACK and TSDDL questionnaires, respectively.

Table 1. The TPACK Questionnaire Blueprint

Variable	Aspect	item		Σ
		Favourable	Unfavourable	
TPACK	Content knowledge (CK)	1,2	4,11	4
	Technological knowledge (TK)	5,22	3,6	4
	Pedagogical knowledge (PK)	7,9,13	12,16	5
	Pedagogical content knowledge (PCK)	10,15,17	21,27	5
	Technological content knowledge (TCK)	18,20	8,25	4
	Technological pedagogical knowledge (TPK)	23,24,26	14,19	5

Examples of statements from the TPACK questionnaire are provided in Table 2.

Table 2. Example Statements from the TPACK Questionnaire

Statements	Answer						
I am able to master the material taught.	1	2	3	4	5	6	7
I am able to relate the concepts in the subject matter to the real world and students' experiences.	1	2	3	4	5	6	7
I am unable to carry out learning activities with students that involve technology.	1	2	3	4	5	6	7
I was unable to master the material taught.	1	2	3	4	5	6	7

In addition to the TPACK questionnaire blueprint, a TSDDL questionnaire blueprint is provided, which is based on six key aspects, as shown in Table 3.

Table 3. The TSDDL Questionnaire Blueprint

Aspect	Item		Σ
	Favourable	Unfavourable	
Skill in diagnostic assessment	1, 2, 4	8, 9, 18	6
Skill in planning	6, 7, 10	13, 20	5
Skill in learning	12, 14, 16, 19	3, 15, 23	7
Ability to perform reflection and evaluation	17, 21, 22	5, 11	5

Examples of statements from the TSDDL questionnaire are provided in Table 4.

Table 4. Example Statements from the TSDDL Questionnaire

Statements	Answer						
I am able to design diagnostic assessment instruments that integrate technology effectively.	1	2	3	4	5	6	7
I am able to use appropriate diagnostic assessment instruments to identify students' strengths and weaknesses in learning.	1	2	3	4	5	6	7
I am unable to complete learning using a variety of media as supporting tools.	1	2	3	4	5	6	7

I am able to analyse students' diagnostic results comprehensively.	1	2	3	4	5	6	7

The instruments were subsequently tested for validity and reliability to ensure their accuracy and consistency. This research employed both content and construct validity tests. Content validity was evaluated by experts from the Elementary School Teacher Education Department at Universitas Ahmad Dahlan, while construct validity was measured using Pearson correlation, resulting in 27 valid items for the TPACK questionnaire and 23 valid items for the TSDDL questionnaire. Reliability analysis, conducted using Cronbach's alpha, revealed a coefficient of 0.971 for the TPACK questionnaire and 0.968 for the TSDDL questionnaire, both indicating high reliability, with values significantly above the 0.70 threshold.

Data Analysis Technique

This research employs both descriptive and inferential statistical data analysis. Descriptive statistics are used to summarize TPACK scores and teacher skills in developing differentiated learning. The descriptive analysis involved calculating the mean and standard deviation, and categorizing the data into high, medium, and low levels based on the criteria outlined in Table 5.

Table 5. Categorization Reference

high	:	$M + 1SD <= X$
moderate	:	$M – 1SD < X < M + 1SD$
low	:	$X < M – 1SD$

Key:
X : Score
M : Mean
SD : Standard deviation

Inferential statistics were used to test the research hypotheses. Before conducting hypothesis testing, prerequisite tests for normality and linearity were performed. The hypothesis was tested using correlation analysis, involving one independent variable and one dependent variable on an interval scale. The correlation coefficient was calculated using the Pearson product-moment correlation to examine the relationship between TPACK and teacher skills in developing differentiated learning. The analysis was conducted using Jamovi software.

Hypothesis

H_0 = There is no significant relationship between TPACK and TSDDL

H_a = There is a significant relationship between TPACK and TSDDL

RESULTS

Table 6 presents the results of the Kolmogorov-Smirnov normality test, as indicated in the Sig. column of the output section.

Table 6. Tests of Normality

Tests of Normality						
	Kolmogorov-Smirnov[a]			Shapiro-Wilk		
	Statistic	df	Sig.	Statistic	df	Sig.
CK	.163	84	**.000**	.921	84	.000
TK	.158	84	**.000**	.942	84	.001
PK	.199	84	**.000**	.888	84	.000

Tests of Normality						
	Kolmogorov-Smirnov[a]			Shapiro-Wilk		
	Statistic	df	Sig.	Statistic	df	Sig.
PCK	.136	84	**.001**	.958	84	.008
TCK	.181	84	**.000**	.897	84	.000
TPK	.169	84	**.000**	.931	84	.000
skill in diagnostic assessment	.131	84	**.001**	.929	84	.000
skill in planning	.099	84	**.041**	.928	84	.000
skill in learning	.130	84	**.001**	.964	84	.019
skill in evaluation	.123	84	**.003**	.949	84	.002
TSDDL	.108	84	**.018**	.950	84	.003
Unstandardized Residual	.062	84	.200*	.977	84	.145

*. This is a lower bound of the true significance.

a. Lilliefors Significance Correction

Table 7 shows that a significance value (Sig) greater than 0.05 indicates a normal distribution. Based on the results of the normality test, it is concluded that the data does not follow a normal distribution. The results of the linearity test are provided in the ANOVA table's Sig. column in Table 7.

Table 7. Linearity Test Results

	F	Sig.
TSDDL * CK	202.538	0.000
TSDDL * TK	307.411	0.000
TSDDL * PK	283.867	0.000
TSDDL * PCK	483.547	0.000
TSDDL * TCK	324.446	0.000
TSDDL * TPK	517.315	0.000

According to the criteria, Table 7 displays a significance level of 0.000; since this value is less than 0.05, the data is considered linear. Thus, we conclude that the research data is linear in all cases. The prerequisite tests for analysis, including normality and linearity tests, yielded the following findings: the data is linear but not normally distributed. Given these conditions, the researcher opted to use a non-parametric test, specifically Spearman's rank correlation, for the subsequent hypothesis testing.

The results of the data categorization analysis are presented in Figure 1.

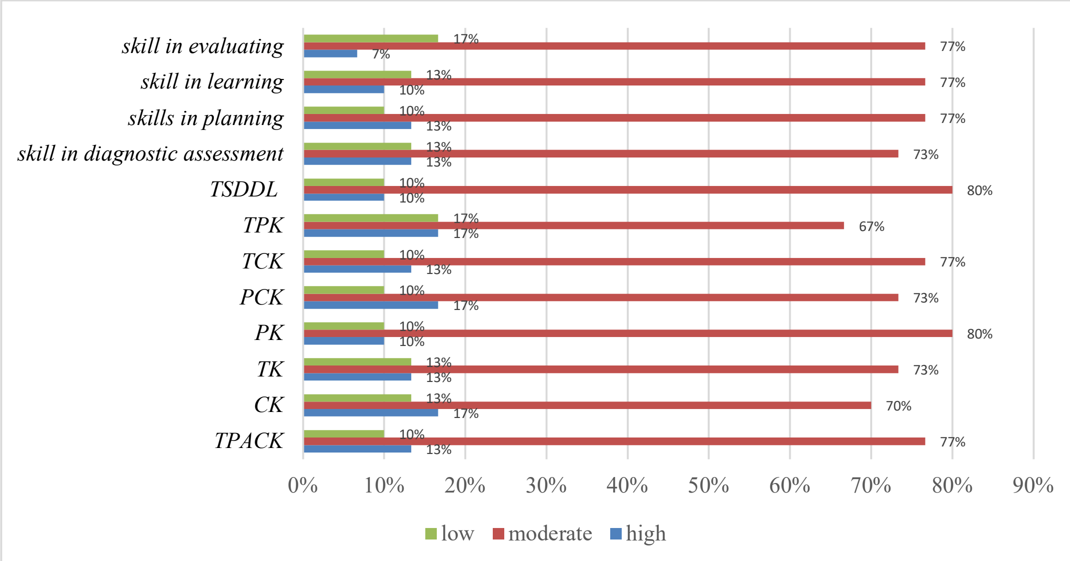

Figure 1. Percentage of TPACK and TSDDL Data Categories and Their Aspects

According to Figure 1, the majority of indicators are at a medium level. Specifically, the TPACK indicator shows that 77% fall within the medium range, while CK reflects 70% at a medium level. Similarly, the TK indicator has 73% in the medium range. Pedagogical Knowledge (PK) stands out with 90% at the medium level, while PCK and TCK are represented by 73% and 77%, respectively, at the medium level. Technological Pedagogical Knowledge (TPK) recorded 67% in the medium range. In contrast to the other indicators, the majority of Digital Intelligence (DI) skills are at a high level, with 90% in this category. Medium values also dominate diagnostic indicators, accounting for 74%. In conclusion, while most indicators are at a medium level, Digital Intelligence skills are notable for their predominance at the high level.

Table 8 displays the results of the Spearman test for the relationship between TPACK aspects and TSDDL.

Table 8. Correlation between TPACK aspects and TSDDL

TPACK	R_{table}	R_{count}	Decision
TPACK	0,2146	0.894	significant
CK	0,2146	0,797	significant
TK	0,2146	0,907	significant
PK	0,2146	0,882	significant
PCK	0,2146	0,908	significant
TCK	0,2146	0,902	significant
TPK	0,2146	0,900	significant

Table 8 presents the results of the correlation test by comparing Rtable with Rcount. The data indicates a significant relationship between each TPACK indicator and the TSDDL variable, as Rcount exceeds Rtable. The correlation results for each TPACK indicator in relation to teacher skills in developing differentiated learning range from 0.60 to 0.799, indicating a strong correlation, and from 0.80 to 1.00, indicating a very strong and positive relationship. This suggests a close connection between changes in one variable and corresponding changes in another. Table 8 reveals that the CK variable has the lowest Rcount at 0.797, while the PCK aspect has the highest at 0.908. The Rcount values confirm a significant relationship between TPACK, CK, TK, PK, PCK, TCK, and TPK with the TSDDL variable.

DISCUSSIONS

TPACK is crucial in the field of education (Padmavathi, 2017). It encompasses teachers' skills in integrating technology, content, and pedagogy, enabling them not only to impart knowledge but also to leverage technology to enhance learning (Crompton, 2015). TPACK represents a comprehensive framework where the mastery of technology is intertwined with its core components—Content (C), Pedagogy (P), and Technology (K)—within the learning process (Häkkinen et al., 2017; Kaplon-Schilis & Lyublinskaya, 2020). Research indicates that TPACK can improve both teaching practices and student learning outcomes across various subjects (Chotimah et al., 2022; Maipita et al., 2023; Usman et al., 2024). For effective educational practice, teachers need experience in combining content and pedagogical strategies (Alrwaished et al., 2017). TPACK can be employed to enhance educational practices and has a direct and simultaneous impact on teaching effectiveness. Teachers with a strong understanding of learning materials are better equipped to develop differentiated instruction.

Content Knowledge (CK) significantly influences teachers' ability to prepare instructional materials (Kim & Ko, 2020). CK involves understanding "what to teach" and "with what material," whereas Pedagogical Knowledge concerns deciding "how to teach" using the appropriate knowledge structure. Curriculum frameworks guide the implementation of content as the primary source of knowledge for instructional activities (Chi et al., 2018). Technological Knowledge (TK) involves a foundational understanding of technology to support learning (Kaplon-Schilis & Lyublinskaya, 2020; Prasetiyo & Suyatno, 2021). This includes using software, animation programs, internet resources, molecular models, and virtual laboratories. Teachers must be proficient in using broadcast software to create educational videos. Additionally, they should stay current with technological advancements, such as augmented reality in teaching (Eduardo et al., 2021; Turkan et al., 2017). This requires teachers to be open to technology and its applications in daily life (Cravens & Hunter, 2021).

Pedagogical Knowledge (PK) encompasses a profound understanding of teaching and learning theories and practices, integral to a teacher's professional expertise. This knowledge includes the use of various tools, such as learning objectives, instructional processes, assessment methods, and teaching strategies. PK is essential for designing and delivering effective instruction that meets the diverse needs of students. By mastering PK, teachers can adapt their approaches to align with student characteristics, thereby creating meaningful and impactful learning experiences (Anggraeni & Ratnaningsih, 2020; Liu et al., 2015; Buyong et al., 2020; Van Driel & Berry, 2012).

Pedagogical Content Knowledge (PCK) represents the intersection of pedagogy (P) and content (C). Research underscores the significant influence of PCK on instructional practices and student academic outcomes (Lucenario et al., 2016). PCK is pivotal in the effective delivery of curriculum-based learning materials, as it guides teachers in choosing the most appropriate technologies to enhance understanding. This aligns with Koehler and Mishra's findings, which emphasize that teachers must grasp how content can shape technology selection and how the right technologies can support content delivery, thus expanding the concept of Technological Content Knowledge (TCK) beyond mere content presentation.

Technology has the potential to transform or create new content, clarifying previously ambiguous material. Consequently, teachers must innovate in developing effective teaching materials and media for classroom use. This includes exploring digital-based learning management through a multimodal approach, which aligns with the idea of utilizing technology to transform teaching materials (Lestari, 2022). Such innovations contribute to the discourse on cutting-edge teaching practices that leverage technology to enhance educational content and its delivery. Research on platforms like Kahoot exemplifies the significant impact of technology on teaching practices. Studies have demonstrated the effectiveness of technology-based instructional media, such as Kahoot, in improving learning outcomes and increasing student engagement (Bhuana, 2023; Muna et al., 2023).

CONCLUSION

This research identified a significant correlation between Technological Pedagogical Content Knowledge (TPACK) and the development of differentiated learning in elementary schools. The findings indicated that most TPACK indicators were at a moderate level, while digital intelligence skills were notably high. The strong to very strong correlation between TPACK indicators and teacher skills suggests that effective TPACK development can significantly enhance differentiated learning. However, the study's limitations, such as the small sample size and the exclusive use of a quantitative approach, may not fully capture the complexities of teacher perceptions. Future research should involve larger sample sizes and incorporate mixed-method approaches to provide a more comprehensive understanding. The implications of this research emphasize the critical need for continuous professional development to improve teachers' TPACK competencies. Additionally, there is a pressing need for educational policies that support training programs aimed at enhancing TPACK skills and digital intelligence. Researchers are also encouraged to develop more comprehensive evaluation tools to better assess the effectiveness of TPACK implementation in differentiated learning.

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