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Analysis of HOTS-Based TPACK Ability Based on Self-Assessment of Teacher Professional Education Students

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Abstract. In the era of 21st-century education, mastery of Technological Pedagogical Content Knowledge (TPACK) is not enough without having higher-order thinking skills (HOTS). This study aimed to analyze HOTS-based TPACK ability in the field of Elementary School Teacher Education (ESTE). This study employed a quantitative descriptive approach with a survey design and data collection through self-assessment instruments. 1644 ESTE students of Teacher Professional Education (TPE) who filled out the instrument from various regions in Indonesia. The students consisted of 94 prospective teachers (Pre-service teachers of TPE) and 1550 TPE students who had become teachers (In-service teachers of TPE). The results showed that ESTE students of TPE showed very good mastery of HOTS-based TPACK. In the Content Knowledge aspect, 90% of students were categorized as having a high level of competence, indicating strong mastery. The ability to solve problems (53.7%) and evaluate student understanding (55.3%) were categorized as medium. In the Pedagogical Knowledge domain, the ability to manage classrooms (69.2%) and select appropriate learning strategies (66.5%) fell into the high category. For Technological Knowledge, 76.2% of students demonstrated a high ability to utilize technology effectively, although 16.9% still had difficulties in evaluating software, which was classified as low. Meanwhile, in the integrative TPACK aspect, 62.8% of students were in the high category in assessing student learning outcomes using a HOTS-based approach. In conclusion, ESTE students of TPE showed very good mastery of HOTS-based TPACK competencies, with high abilities in content knowledge, pedagogy, and technology even though challenges in evaluating software remain to exist. This study implies the need to strengthen training in technology evaluation and the application of higher-order thinking skills to ensure comprehensive and sustainable TPACK competence in teacher education programs.

Keywords: HOTS; Teacher Professional Education; Elementary School Teachers; TPACK

1. Introduction

Digital technology is currently an inseparable part of individual life, both in educational environments and in society at large (Haleem et al., 2022). The development of information and communication technology (ICT) in the world of education opens up new opportunities in the learning process. Accordingly, educators are expected to have adequate competence to encourage active involvement in the use of digital technology. This competence is not only important for the effective use of technology but also to guide students in developing their digital literacy and skills (Spante et al., 2018). Teachers and education personnel must be ready to face changes so that learning remains relevant to the times. Teachers not only have to be able to use technology but also integrate it effectively into learning practices (Nanola et al., 2024). With the support of emerging technology, the learning process can become more interactive, adaptive, and relevant to the needs of the times (Mahrani et al., 2023).

On the other hand, the main challenge for teachers is the ways to integrate technology, pedagogy, and content effectively to achieve quality learning goals. One approach that is now increasingly recognized in learning is TPACK, which is the ability of teachers to combine knowledge of technology, pedagogy, and content in an effective learning process. (Taopan et al., 2020) explained that TPACK describes the ability of teachers to make appropriate and creative decisions in the use of technology in the classroom. Manaff & Azahari (2024) stated

that the development of digital technology has brought significant changes in the world of education, making technology an important element integrated into teaching and learning activities between teachers and students. This transformation also influences the way interactions and learning processes in an increasingly technological environment.

TPACK plays a crucial role in 21st-century learning because technology is now embedded in everyday life. Currently, the younger generation is known as digital natives, namely the generation that grew up and developed with technology, so they are very accustomed to using it in various activities (Rahayu et al., 2024). The role of teachers is no longer limited to conveying information. Teachers' role also as facilitators who can utilize technology to create active, collaborative, and contextual learning (Sailer et al., 2021). Therefore, every educator must have the ability to use technology integration in learning. This is in line with the Regulation of the Minister of National Education No. 16 of 2007, stating that teachers are required to master TPACK as a means to develop themselves and improve the quality of student learning. This provision is reinforced by Permendikbud No. 22 of 2016 in the learning process standards, emphasizing that teachers must be able to utilize ICT to increase the efficiency and effectiveness of teaching and learning activities (Fakhriyah et al., 2022). This increasingly rapid demand for change also needs to be balanced with an education system that is relevant and adaptive to current developments.

The development of digital technology, changes in the needs of the world of work, and the shift in the educational paradigm from teacher-centered to student-centered encourage the need for reform in educational approaches (Andrea et al., 2024). In this context, ESTE students of TPE as prospective educators at the elementary education level not only need to master the teaching materials but also to be able to adapt to these dynamics. ESTE students of TPE need to have competence in integrating technology, implementing student-centered learning strategies, and understanding student characteristics in more depth. Thus, ESTE students of TPE need to be equipped with approaches and skills that support their role as agents of change in the ever-evolving world of education. This demands a transformation in the educational process, especially in preparing prospective educators who can cope with these challenges. Therefore, higher education has an important role in developing the abilities of ESTE students of TPE, especially in implementing TPACK to design learning tools (Chang et al., 2024). Students must be able to integrate technology, pedagogy, and content knowledge appropriately to create evidence-based learning experiences that meet learners' needs (Vignare & Lorenzo, 2020).

In this increasingly complex era of education, having only the ability to develop TPACK is not enough. In this context, HOTS is very important to consider because HOTS includes skills such as analysis, synthesis, evaluation, and creativity needed to encourage students to not only master knowledge but also to think critically and innovatively in facing the challenges of the times. HOTS is the ability to process a fact, understand it deeply, draw conclusions, connect it with other information innovatively, and use it to solve problems (Jaenudin et al., 2020). Referring to Bloom's Taxonomy, HOTS requires mastery of high-level thinking skills such as analysis, evaluation, and creation (Practice & Bloom, 2008). Critical thinking skills are essential to master these skills (Sidiq et al., 2021). In addition, Rati et al., (2023) stated that HOTS is a harmonious and essential part of 21st-century learning. In this context, individuals need to be active in seeking and building their own knowledge, while still getting guidance from teachers as learning facilitators. Therefore, elementary school teachers or ESTE students of TPE need to be able to integrate technology into the elementary school curriculum in a meaningful way, not just as an addition, but as an element that strengthens and deepens the learning process.

In line with these changes, prospective teachers and teachers who take part in TPE are expected not only to master TPACK but also to be able to develop HOTS in teaching. Therefore, it is important to know the HOTS-based TPACK profile of pre-service teachers and in-service teachers of TPE students in the ESTE context, as well as how optimally they can apply the integration of technology, pedagogy, and content in encouraging critical and creative thinking skills in students. TPE of ESTE requires participants to have an appropriate academic

educational background because this program is designed to guide participants systematically and in a structured manner in applying academic knowledge obtained at the undergraduate level (Rokhman et al., 2024).Through TPE of ESTE, participants are oriented to master professional competencies that are the basis for gaining recognition as professional teachers in the field of elementary school education. One important aspect of this professional competency is the ability to utilize ICT and HOTS (Almerich et al., 2024). These teacher competencies play an important role in improving student performance and achievement. The higher the competence a teacher has, the greater the possibility of improving student learning outcomes (Symeonidis, 2019).

This is also relevant for ESTE students of TPE, who are expected to develop their competencies to provide more effective teaching and have a positive impact on student development because a teacher needs to have good competencies and high professionalism to improve student knowledge and skills (Ludwikowska, 2019). Therefore, ESTE students of TPE need to obtain these competencies during professional education, so that they are ready to become teachers who can improve the quality of learning, achievement, and student learning outcomes in the future. The application of TPACK integrated with HOTS is expected to develop the ability of ESTE students of TPE to compile and implement learning that not only relies on basic understanding but also encourages students to think critically, and creatively, and be able to solve problems innovatively. Thus, mastery of HOTS-based TPACK not only improves teacher competency in managing technology-based learning but also encourages students to achieve higher and more meaningful learning outcomes. This study aimed to analyze and describe how HOTS-based TPACK was applied to pre-service and in-service teachers of TPE. In this context, this study observed how effectively prospective pre-service and in-service teachers of TPE can develop TPACK competencies with the HOTS approach, resulting in more meaningful learning and improving the quality of education in the future.

1.1. Problem Statement

Integration between TPACK and HOTS in learning is very important, especially in the context of 21st-century learning. In the digital era, technology is used not only as a tool but also must be used to improve individual high-order thinking skills. Teachers who have a good understanding of HOTS-based TPACK can design learning that combines the use of appropriate technology with pedagogical strategies that can facilitate, stimulate, and stimulate high-order thinking skills in students (Susantini, et al., 2022).

The main problem faced by the researcher is the discrepancy between the theoretical importance of integrating Higher-Order Thinking Skills (HOTS) and Technological Pedagogical Content Knowledge (TPACK) in 21st-century education and the practical limitations in teachers' ability to implement this integration effectively. Although the study demonstrates a generally high level of HOTS-based TPACK mastery among ESTE students, it also reveals specific challenges, particularly in evaluating educational software and applying pedagogical strategies that foster HOTS. These issues are caused by limited practical training, insufficient exposure to critical technology evaluation, and contextual disparities in access to educational resources. As a result, there is a risk of suboptimal student learning outcomes, inconsistent teaching quality, and the underutilization of technology as a transformative learning tool. To address these challenges, further investigation using mixed-methods approaches is necessary to explore the depth of these issues and their contextual factors. This is important to ensure that teacher education programs can effectively prepare educators who are capable of designing and delivering instruction that meets the cognitive demands of 21st-century learners.

Several studies have shown that the use of appropriate technology can support students' development of HOTS. Technology plays a significant role in supporting students' development of Higher Order Thinking Skills (HOTS) by providing innovative and interactive learning environments. Various studies have explored how digital tools and resources can enhance critical thinking, creativity, and problem-solving skills among students. These tools include e-modules, electronic worksheets, and ICT tools, which are designed to facilitate a deeper understanding and application of knowledge. The following sections detail how technology

supports HOTS development. E-modules, such as those developed using platforms like Canva, have been shown to be effective in improving students' reading skills and overall academic performance. These modules are designed to be valid, practical, and effective, as evidenced by student achievements and expert evaluations(Maiza et al., 2024).Factors such as the use of information and communication technology (ICT) tools, along with the instructor's approach, student engagement, learning materials, and organizational support, significantly influence the effectiveness of technology in fostering HOTS (Letchumanan, 2022).Technology supports students' development of higher order thinking skills (HOTS) by fostering positive attitudes towards its use, which directly influences HOTS promotion (Letchumanan, 2023). The study indicates that the use of ICT in schools can have a complex impact on students' higher-order thinking skills (HOTS) (Sun, et. al., 2022). TPE of ESTE is an educational program designed to prepare prospective teachers with the professional skills needed in the world of education. This program aims to improve teacher competence in various aspects, including mastery of TPACK and the application of HOTS in the learning process. In the context of TPE, prospective teachers are taught to master various learning methods that can effectively integrate technology into teaching. In addition, students are also given training to develop high-order thinking skills, both in designing learning that can facilitate and encourage students to think critically and in choosing and utilizing technology that supports the achievement of these goals. Therefore, the TPE program has an important role in improving the quality of teacher teaching through the development of TPACK and HOTS.

1.2. Related Research

Several studies relevant to this topic show the importance of developing TPACK in learning. For example, research conducted by Tanak (2020) shows that developing TPACK in teachers can improve the effectiveness of learning that integrates technology. In addition, research done by Tyas & Naibaho (2021) emphasizes the importance of HOTS integration in the use of technology to improve the quality of learning oriented toward developing students' critical thinking skills.

The existing studies by (Wakhidah & Lodhi, 2025) and Yanuarto et al.,(2025)) primarily focused on the influence of specific TPACK components—such as Technological Pedagogical Knowledge (TPK), Technological Content Knowledge (TCK), and Content Knowledge (CK)—on lesson plan quality and their correlation with teachers' ability to stimulate HOTS in students. These studies emphasized the theoretical relationship and partial effects of TPACK elements on HOTS but did not comprehensively assess the integrated mastery of HOTS-based TPACK among a large and diverse population of teacher education students. In contrast, the novelty of this research lies in its large-scale, empirical analysis of HOTS-based TPACK competence among 1,644 TPE students across various regions in Indonesia, including both pre-service and in-service elementary school teachers. This study provides a more holistic and practical overview of how well TPE students can integrate HOTS within the TPACK framework, identifying specific strengths and weaknesses in real educational contexts. The state of the art of this research is its unique focus on the direct measurement of HOTS-based TPACK mastery through self-assessment, contributing valuable insights into the preparedness of future educators to meet the cognitive demands of 21st-century learning in the digital era.

1.3. Research Objectives

This study aims to analyze and describe the competency profiles of Technological Knowledge (TK), Pedagogical Knowledge (PK), Content Knowledge (CK), Technological Content Knowledge (TCK), Technological Pedagogical Knowledge (TPK), and TPACK in pre-service and in-service ESTE teachers of TPE students. Each competency is analyzed to see the extent to which students can integrate technological, pedagogical, and content knowledge in the learning planning process that supports the development of high-order thinking skills.

This study is limited to the analysis of the TPACK profile based on HOTS in pre-service and in-service ESTE teachers of TPE students in several regions in Indonesia. This study focuses on the

ability of teachers to integrate TPACK with HOTS in the context of learning and does not discuss external factors such as educational policies or facilities and infrastructure available in schools.

2. Theoretical Framework

This study includes a theoretical framework that comprises the concepts of TPACK, and HOTS.

2.1. Technological Pedagogical Content Knowledge *(TPACK)*

The TPACK concept introduced by Mishra & Koehler, (2006)emphasizes the importance of integrating three main domains of knowledge that teachers need to have to teach effectively in the digital era. The three domains include CK, which is a deep understanding of the subject matter being taught such as science, mathematics, or language that includes theory, facts, and procedures. The next domain is PK which includes mastery of learning strategies, classroom management, and the ability to adjust learning approaches based on students' needs and characteristics. Meanwhile, TK refers to the ability to use various digital devices and technologies such as software, hardware, and learning platforms to support the teaching and learning process.

TPACK can be used as a basic framework for designing an educational curriculum that is relevant to the demands and developments of 21st-century learning (Ragil et al., 2022). TPACK emphasizes the importance of the integration of technological knowledge, pedagogy, and content to create effective and relevant learning in the digital era. A thorough understanding of the indicators in each material is needed to assess the strength of the integration of the three components conducted by ESTE students of TPE in carrying out the learning process. The findings of this study can be used as a consideration in formulating an educational curriculum for prospective elementary school teachers to create professional teachers in the 21st century (Saptani et al., 2024). The TPACK framework emphasizes that the effectiveness of learning not only depends on one type of knowledge but also the synergistic interaction between the three elements. Teachers who can integrate the three appropriately can create better meaningful and relevant learning experiences for students in the 21st century.

2.2. Higher Order Thinking Skills (HOTS)

HOTS or high-order thinking skills are an important aspect in developing students' cognitive abilities that include complex thinking activities such as analysis, synthesis, evaluation, and creativity. These skills go beyond simply remembering or understanding basic information and require students to be able to process information deeply and reflectively. HOTS-based learning is an important approach in efforts to develop students' high-order thinking skills. Teachers can equip students with the skills needed to compete in the era of globalization through the application of this learning (Isrokatun et al., 2024). The purpose of HOTS-based learning is to prepare students to be able to think critically and creatively in facing real-world challenges, as well as to become lifelong learners who can adapt to changes and developments in the future (Musi, 2023).

(Syafryadin et al., 2021) stated that HOTS is classified into several main categories, including the ability to analyze information by breaking it down into small parts and identifying patterns; the ability to synthesize information from various sources into a new idea; the ability to evaluate arguments or ideas based on certain criteria; and the ability to be creative by producing or modifying ideas innovatively. The application of HOTS in learning is crucial to forming students' critical, analytical, and solution-oriented thinking patterns so that they can adaptively respond to the challenges of the times. Therefore, teachers have a strategic role in designing learning activities that can foster and train students' HOTS systematically.

3. Method

3.1. Research Design

This study applied a quantitative descriptive approach, which a method used to objectively describe the nature and magnitude of sensory characteristics (Sidel, et. al., 2018). That aimed to map the TPACK profile based on HOTS in pre-service and in-service teachers who are participants in the TPE program. This approach was chosen because it allows researchers to describe phenomena objectively and systematically without conducting hypothesis testing or generalization of a wider population.

A survey design was chosen to systematically collect data using a structured self-assessment questionnaire distributed online to 1,644 respondents from various regions in Indonesia, including 94 pre-service and 1,550 in-service teachers. The instrument measured participants' abilities across the core TPACK domains—Content Knowledge, Pedagogical Knowledge, and Technological Knowledge—with a focus on higher-order thinking skills, using a Likert scale to capture levels of competence. Data collection was conducted digitally with informed consent and ensured confidentiality. Descriptive statistical analysis, including frequency and percentage distributions, was applied to categorize students' mastery levels in each domain. Prior to the full study, the questionnaire was validated by experts and tested for reliability through a pilot study, confirming its appropriateness for measuring HOTS-based TPACK. This research method allowed for an objective, comprehensive, and systematic mapping of teacher competencies without testing hypotheses or making broader generalizations.

This research used a survey design with data collection techniques through self-assessment instruments. This instrument was designed to provide an in-depth picture of the level of respondents' mastery of the TPACK dimensions and the implementation of high-order thinking skills in the context of learning. The use of self-assessment is considered effective because it provides space for respondents to reflect and independently evaluate their competencies, especially in terms of integrating content knowledge, pedagogy, and technology in learning practices that encourage the development of HOTS. This design is expected to contribute to a more comprehensive understanding of the readiness of pre-service and in-service teachers to face the demands of 21st-century learning.

3.2. Participants

The population in this study were TPE students of pre-service and in-service teachers who participated in the TPE program in the field of elementary school teacher education in several regions in Indonesia. The sample of this study was selected using a purposive sampling technique by selecting participants based on certain criteria that are relevant to the research objectives. The criteria used in selecting the sample are as follows:

1. Pre-service teachers and in-service teachers of TPE students who have teaching experience or are undergoing teacher professional education.

2. Participants are willing to participate in the research and fill out the self-assessment questionnaire.

In this study, the sample taken consisted of 1644 TPE participants, comprising 94 pre-service teachers and 1,550 teachers who participated in the TPE program. The distribution of the number of participants can be seen in Table 1.

Table 1. The Number of Research Participants

Teacher Group	Number of Participants
TPE Students of Pre-Service Teachers in 2024	81
TPE Students of Pre-Service Teachers in 2023	13
TPE Students of In-Service Teachers Phase 1 of 2024	298
TPE Students of In-Service Teachers Phase 2 of 2024	211
TPE Students of In-Service Teachers Phase 3 of 2024	1,041
Total	1,644

3.3. Data Collection

In this study, data collection was carried out through a self-assessment method specifically designed to measure the HOTS-based TPACK competency profile. The instrument used was a modification of the HOTS-based TPACK instrument from Jalani, et al. (2021). The research instrument consisted of two main components, namely: first, the HOTS-based TPACK questionnaire developed based on the main dimensions of TPACK, namely: (1) CK, reflecting participants' mastery of the teaching material; (2) PK including the ability to design, implement, and evaluate the learning process effectively; (3) TK, concerning the ability to utilize technology to support learning activities; and (4) the integration of the three in TPACK, namely the ability to combine content knowledge, pedagogy, and technology in a cohesive learning strategy. This questionnaire was also designed to explore the extent to which participants applied HOTS, including analysis, synthesis, evaluation, and creativity in the context of learning. Second, the questionnaire instrument was presented using a four-point Likert scale, namely: (1) Strongly Disagree, (2) Disagree, (3) Agree, and (4) Strongly Agree. Participants were asked to rate their level of mastery of various TPACK indicators and HOTS applications based on their own experiences and self-perceptions. This technique allowed researchers to obtain a subjective but informative picture of the perceptions of competence of prospective teachers and TPE teacher participants.

3.4. Data Analysis

The data obtained from the self-assessment questionnaire were analyzed using quantitative descriptive analysis. Some of the analysis steps taken were as follows:

1. Frequency and Percentage Analysis: To describe the distribution of participants' answers to each question item.
2. Average Calculation: To find out how high the overall mastery of HOTS-based TPACK is by pre-service and in-service teachers of TPE.
3. Profile Comparison: If necessary, a comparison is made between the HOTS-based TPACK profiles between pre-service and in-service teachers of TPE.

3.5. Validity and Reliability

To ensure the quality of the data obtained, the research instrument used in the form of a questionnaire was tested for validity and reliability. Content validity was carried out using the Aiken test by asking for the opinions of 7 experts in the field of education and technology with a V-Aiken value of 0.85 (valid), while reliability was tested using Cronbach's alpha to ensure the internal consistency of the instrument. The Cronbach's alpha value for this instrument was 0.75 (valid).

4. Findings

The findings of this study analyzed the ability of ESTE students of TPE to implement the HOTS-based TPACK framework, with a focus on how ESTE students of TPE synergistically integrated technological, pedagogical, and content knowledge in designing and implementing learning that encourages high-order thinking skills in students.

4.1. Dimension of Technological Knowledge (TK)

The results of the analysis on the TK dimension of the 6 statement items are presented in Table 2. The results of the analysis for each item on the TK dimension are described in Table 2 below: a) Strongly Disagree (1), b) Disagree (2), c) Agree (3), d) Strongly Agree (4).

Table 2. HOTS-based TK Competencies of ESTE Students of TPE

Questions	Score			
	1	2	3	4
I can utilize appropriate technology in the learning activities.	36	27	340	1,252
I have difficulty connecting the appropriate technology function to the process.	184	185	468	818
I can choose the right teaching aids for the learning activities.	19	34	456	1,146
I can adjust teaching aids in the learning activities.	18	29	476	1,132
I have difficulty finding the advantages and disadvantages of the software/applications used in learning activities.	139	278	629	609
I can choose software (media/applications) that is appropriate to the learning materials.	15	69	568	1,003

The results of the data analysis provided in Table 2 show that the majority of participants felt quite confident in utilizing technology and teaching aids in their learning. In the statement regarding the ability to utilize appropriate technology in learning, almost all participants gave a high score, with 1,252 people choosing a score of 4, indicating that they felt capable of utilizing technology in the teaching and learning process. Similar things could be also seen in the ability to choose and adjust teaching aids, where most participants felt capable, with a significant number giving a score of 4 to both statements. However, there were several challenges faced by a small number of respondents. For example, in the statement regarding the difficulty of connecting the function of technology with learning, although most gave a score of 3 and 4, there were around 184 people who found it difficult (giving a score of 1) and 185 people who gave a score of 2. This indicated a challenge in understanding in depth how technology can be integrated into learning. In addition, although the majority of participants felt capable of choosing software that is appropriate to the learning material, there were still those who found it difficult to evaluate the advantages and disadvantages of the software or applications used in learning, with 139 people giving a score of 1 and 278 people giving a score of 2.

Based on the data presented, most participants felt confident in utilizing technology for learning, especially in selecting and adjusting the teaching aids and software used. This reflected a good understanding of the content dimension in the use of educational technology. In the TPACK theory proposed by (Mishra & Koehler, 2006), it is stated that the selection of the right technology is highly dependent on the knowledge of the content being taught. This means that teachers need to understand the material being taught and be able to choose technology that supports specific learning objectives. The data showed that respondents had a good understanding of selecting appropriate tools and applications, which

supports the theory that content knowledge is the basis for selecting relevant technology. However, challenges emerged in the technology dimension itself. Some participants found it difficult to connect technology with the learning process, as well as to evaluate the advantages and disadvantages of the software used. This indicated limitations in the technological knowledge needed to utilize technology optimally. Venkatesh et al. (2003) in the Model of Information Technology Adoption suggested that technology acceptance is influenced by ease of use and perceived benefits. When teachers feel that the technology used is difficult or does not provide clear benefits, they will have difficulty integrating the technology into their learning process. However, most participants felt able to utilize technology well when the pedagogical dimension was considered. In this regard, Falloon (2020) in their research emphasized the importance of mastering digital competencies that are not only related to the use of technological tools but also to the ability to adapt technology to teaching methods that suit students' needs. Teachers need to develop pedagogical skills in choosing technology that can support students' learning styles, as well as being able to critically evaluate the tools used. Training that focuses on this dimension can greatly help overcome the challenges faced by some participants in connecting technology to learning more effectively.

4.2. Dimension of Pedagogical Knowledge (PK)

Based on Table 3, the results of the PK recapitulation showed that the majority of teachers felt quite competent in managing learning: compiling assessments, managing classes, choosing learning strategies, and compiling learning method steps. The results of the analysis of HOTS-based PK dimensions can be seen in Table 3 below.

Table 3. HOTS-based PK Competencies of ESTE Students of TPE

Questions	Score			
	1	2	3	4
I can compile the assessment form correctly based on the characteristics of the learning materials.	14	52	614	975
I can manage the class so that students do not get bored with learning.	15	36	468	1,137
I can choose learning strategies based on students' needs.	16	25	520	1,094
I have difficulty compiling learning method steps to make it easier for students to understand the materials.	158	194	498	805

In this study, the PK dimension reflected the extent to which ESTE students of TPE understood and were able to apply pedagogical principles in learning practices. One indicator was the ability to compile assessment forms that were in line with the characteristics of the learning materials. The results showed that 975 respondents gave a score of 4 and 614 respondents gave a score of 3, which reflected high confidence in this ability. The ability to design relevant assessment forms is very important in the learning process because assessment is not only a measuring tool but also an integral part of a pedagogically designed learning strategy. Assessments that are aligned with objectives and teaching materials, as stated by (Wiggins, 1999), contribute to improving student understanding and strengthening high-order thinking skills. In addition, the ability to manage the class to create a pleasant learning atmosphere also showed good pedagogical mastery. A total of 1,137 respondents stated that they were very capable (score 4), and 468 others felt quite capable (score 3) in preventing student boredom during learning. This indicated that the majority of participants had classroom management skills that support the creation of active and dynamic learning. Emmer and Sabornie (2015)

stated that effective classroom management includes creating a positive learning environment, implementing clear rules, and varying methods and activities to maintain student engagement.

The ability to choose learning strategies that suit students' needs also received a positive response, with 1094 respondents choosing the highest score, and 520 respondents in the fairly capable category. This reflected participants' awareness of the importance of an approach that is oriented towards student needs. Appropriately selected learning strategies, such as the differentiation approach explained by Tomlinson, (2011), allow teachers to adjust methods and materials to students' learning styles so that learning becomes more effective and meaningful. However, some challenges in terms of compiling learning method steps remained. Although 805 respondents felt very capable, and 498 respondents were quite capable in compiling them, there were also 194 respondents with a score of 2 and 158 respondents with a score of 1 who showed difficulties. This showed that although the understanding of pedagogical principles was generally quite good, the aspect of designing learning steps was still a point that needed to be improved. Yan, (2023) emphasized that the effectiveness of learning is greatly influenced by the quality of planning and the clarity of the steps in teaching. Therefore, it is necessary to strengthen more structured and strategic learning planning skills to ensure that students can understand the material optimally.

4.3. Dimension of Content Knowledge (CK)

The results of the analysis on the CK dimension from the results of the graduates' responses to the 4 statement items are presented in Table 4.

Table 4. HOTS-based CK Competencies of ESTE Students of TPE

Questions	Score			
	1	2	3	4
I can solve various kinds of problems from various content materials in the subjects I teach (CK)	14	61	698	882
I can develop various kinds of problem-solving from low to high cognitive levels in the subjects I teach.	13	82	774	786
I can make various variations of appropriate assessments.	14	75	718	848
I can evaluate students' understanding of content.	11	59	676	909

Based on the CK recap presented, the majority of respondents felt that they had good abilities in terms of understanding content and applying learning to the subjects they taught. This finding showed that teachers felt quite competent in mastering the subject matter and conveying the knowledge effectively. Assessment of this ability can be seen in several aspects related to understanding and applying learning content.

In the first statement, related to the ability to solve various kinds of problems from various content materials, the majority of respondents (882 on a scale of 4 and 698 on a scale of 3) felt quite competent in mastering various content materials and were able to solve relevant problems. This indicated that in-depth mastery of content is an important foundation for teaching effectiveness. CK is the foundation needed for teachers to teach learning materials effectively and provide appropriate guidance in solving more complex problems (Deng, 2018). Furthermore, in the second statement regarding the ability to develop problem-solving from

low to high cognitive levels, 786 respondents chose a scale of 4, and 774 respondents on a scale of 3.

These results indicated that teachers felt quite capable of designing questions and learning activities that cover various cognitive levels, from basic to more complex. Based on Bloom's taxonomy updated by Anderson and Krathwohl (2001), the ability to design questions with various cognitive levels is very important to encourage the development of students' critical and creative thinking, as well as creating a more dynamic learning experience. The ability of teachers to create appropriate assessment variations is also seen in the third statement, where 848 respondents gave the highest score (scale 4) and 718 respondents on scale 3. Assessment variations, which include written tests, project assignments, or portfolios, are important tools for measuring student achievement from various aspects. According to Nitko and Brookhart (2007), diverse assessments provide a more comprehensive picture of student development and accommodate different learning styles. In this way, teachers can be more precise in evaluating students' understanding of the material. Finally, in the fourth statement about the ability to evaluate students' understanding of content, 909 respondents chose a scale of 4 and 676 on a scale of 3.

These findings indicated that most teachers felt competent in evaluating student understanding. Good evaluation, especially formative evaluation conducted during the learning process, is a key element in providing constructive feedback. Appropriate evaluation not only improves student understanding but also allows teachers to adjust teaching methods based on student needs, improving the overall quality of learning (Pollock & Talone, 2020). Overall, the results of this study indicated that teachers had a strong understanding of the content and were able to apply their knowledge in various aspects of learning, from problem-solving to assessing and evaluating student understanding. This competence is very important for creating effective and in-depth learning for students.

4.4. Dimension of Technological Content Knowledge (TCK)

The results of the analysis on the HOTS-based TCK dimensions from the results of the participants' responses to the 8 statement items are presented in Table 5.

Table 5. HOTS-based TCK Competencies of ESTE Students of TPE

Questions	Score			
	1	2	3	4
I can arrange the sequence of content combined with technology in the subjects I teach.	18	82	758	797
I can choose the right technology (teaching aids/media/software) for the content of the subjects I teach.	17	53	659	926
I can explain the materials by utilizing technology: media, teaching aids, and software in the subjects I teach.	14	59	662	920
I have difficulty preparing material using technology: teaching aids/media and software.	126	155	566	808
I can design the stages of the materials based on the level of understanding of students based on their learning experience.	12	67	697	879

I can choose the appropriate learning method to overcome students' difficulties in understanding the materials.	11	52	639	953
I can arrange the stages of the materials correctly to support the explanation of the materials being taught.	13	59	669	914
I can design lesson plans using the right teaching methods and techniques to develop learning creativity.	11	51	605	988

TCK or content and technology knowledge refers to the ability of educators to understand and utilize technology to deliver materials needed by students. The results of the percentage of achievement in Figure 1 and Table 4 showed that the TCK ability of ESTE students of TPE can be interpreted that the majority of participants showed good ability in integrating technology into the learning process. This was reflected in several aspects, such as the arrangement of content sequences combined with technology, the selection of appropriate technology, and the use of technology in explaining materials.

In the first statement regarding the ability to arrange content sequences that combine technology, the majority of participants, namely 797 people on a scale of 4 and 758 people on a scale of 3, showed good ability. The use of technology in education can enrich the learning experience and facilitate the teaching of material, as expressed by Wibowo (2022) who stated that technology can facilitate learning more interestingly and interactively. In addition, in the second statement regarding the ability to choose the right technology, 926 participants chose a scale of 4, indicating that teachers generally felt capable of choosing the right technology to support learning. Choosing the right learning tools can improve student understanding.

The third statement regarding the ability to utilize technology in teaching material showed that 920 respondents felt quite competent. Technology allows for more flexible teaching and can be adjusted to students' needs, as explained by Pappano (2012), who stated that the use of technology in learning makes the material more interesting and easier to understand. However, in the fourth statement regarding the difficulty in preparing material using technology, there were 808 participants on a scale of 4, indicating that some teachers faced obstacles in integrating technology. This is in line with research conducted by (Kristiawan & Muhaimin, 2019) stating that limited skills or facilities are the main obstacles to the effective application of technology. Then, in the fifth statement regarding the ability to design stages of material based on the level of understanding of students, there was a positive tendency with 879 participants on a scale of 4. Differentiation of learning is very important, allowing teachers to adjust the materials to the needs and level of understanding of students. In addition, in the sixth statement regarding the selection of the right learning method, 953 participants gave the highest rating, indicating that teachers felt capable of choosing the right method to help students understand the materials Farid et al.,, (2022). Lee & Paul (2023) stated that selecting the right method can significantly increase student engagement and understanding. In the seventh statement, the majority of respondents felt able to organize the stages of the material correctly. This reflected the importance of systematic learning planning so that students can understand the material gradually (Mishra & Koehler, 2006) . Finally, in the statement regarding the ability to design lesson plans with the right methods and techniques, 988 respondents felt quite capable, which is consistent with Slavin's (2009) learning planning theory, emphasizing the importance of good planning in improving the quality of education. Overall, the integration of technology in learning showed good progress, although there were still challenges that need to be overcome.

4.5. Dimension of Technological Pedagogical Knowledge (TPK)

The results of the analysis on the HOTS-based TPK dimensions of ESTE students of TPE consisting of 4 questions are presented in Table 6.

Table 6. HOTS-Based TCK Competencies of ESTE Students of TPE

Questions	Score			
	1	2	3	4
I can design stages of learning materials based on the level of student understanding and their learning experience.	10	57	687	901
I can choose appropriate learning methods to overcome student difficulties in understanding the learning materials.	8	39	675	933
I can arrange stages of learning material correctly to support the explanation of the material being taught.	11	48	640	956
I can design lesson plans using appropriate teaching methods and techniques to develop learning creativity.	9	47	680	919

The results of the recapitulation of Table 5 regarding TPK showed that the majority of teachers felt they had good competence in designing learning materials that are in line with student understanding and support creativity. The following is a more detailed discussion related to these results. First, regarding the ability to design stages of material based on student understanding, 901 respondents chose on a scale of 4, indicating that teachers were able to compile materials that are in line with student development. Vygotsky, (2019) in the theory of the zone of proximal development (ZPD), explains the importance of providing challenges that are in line with student abilities. Second, regarding the ability to choose the right learning method to overcome student difficulties, 933 respondents felt able to choose an effective method, such as problem-based learning, which according to Mayer (2014) can improve student understanding.

Furthermore, in the third statement regarding the arrangement of the correct stages of material to support the explanation of the material, 956 respondents felt competent. Gagné (1985) stated that a well-structured sequence of material facilitated student understanding. Finally, in designing lesson plans with the right method, 919 respondents felt able to integrate techniques that support learning creativity, in line with Arends' view (2012), which emphasizes the importance of choosing the right method to develop student creativity in learning.

4.6. Dimension of Technological Pedagogical Content Knowledge (TPACK)

The results of the analysis on the HOTS-based TPACK dimension consisting of 6 statement items, are presented in Table 7.

Table 7. HOTS-Based TPACK Competencies of ESTE Students of TPE

Questions	Score			
	1	2	3	4
I have difficulty integrating technology with the methods used to teach content in the subjects I teach.	117	199	578	761
I can evaluate technology-integrated learning based on indicators in the subjects I teach.	13	83	689	870

I can connect technology (teaching aids/software) to various content teaching in the subjects I teach.	16	65	686	888
I can choose the right media, teaching aids, and applications to solve problems in the subjects I teach.	15	43	628	969
I can assess students' work results in solving problems in the subjects I teach.	12	32	578	1,033
I can prepare the use of certain technologies for solving problems in the subjects I teach.	12	50	635	958

Table 7 showed that TPACK is a combination of knowledge and skills regarding material, pedagogy, and technology in one integrated unit. This integration refers to the unification of various elements to form a complete and mutually supportive system. The findings of this study explored the ability of ESTE students of TPE to integrate technology into learning through the HOTS-based TPACK approach. Based on the results of the data obtained, the majority of participants showed a high level of ability in terms of technology integration, reflected in the dominance of high scores (scores 3 and 4) on almost all questions. This indicated that most students felt comfortable and competent in applying technology in their learning process, showing a positive tendency toward understanding and applying the TPACK framework. In more detail, in terms of the ability to integrate technology with learning methods, most participants (761 people) gave a score of 4, followed by 578 participants with a score of 3, indicating that they did not experience significant difficulties. In evaluating technology-based learning, 870 participants gave a score of 4, and 689 participants gave a score of 3, reinforcing the finding that the majority felt quite capable in this evaluative process. In the aspect of connecting technology with content teaching, 888 participants gave the highest score, while 686 others gave a score of 3, indicating good mastery of the connection between technology and teaching materials. The ability to choose media, aids, and learning applications was also very prominent, with 969 participants giving a score of 4 and 628 participants giving a score of 3, indicating that they were able to determine learning media that were relevant to the needs of the material. In addition, in the aspect of assessing student work results, 1,033 participants felt very capable (score 4) and 578 others were quite capable (score 3), indicating good technology-based assessment skills. Finally, in terms of readiness to use technology to solve learning problems, 958 participants gave a score of 4, and 635 participants gave a score of 3, indicating high readiness to face the challenges of 21st-century learning**.**

5. Discussion

The results of the study indicated that ESTE students of TPE had strong readiness in techno-pedagogical aspects, especially in integrating technology into learning that encourages HOTS. This finding is in line with the TPACK theory which emphasizes the importance of synergy among three main components: content knowledge, pedagogy, and technology (Ning et al., 2024). The ability of participants to evaluate technology-based learning and relate it to teaching materials reflected that they not only understood the use of tools but were also able to use them strategically to achieve more complex learning goals (K. S. Lee, 2014). High ability in choosing media and learning applications showed that TPE students had good digital literacy, as well as awareness of the importance of utilizing appropriate technology. This is very relevant in the context of the *Merdeka* Curriculum, which emphasizes learning oriented toward strengthening character, creativity, and problem-solving. Meanwhile, the high ability to assess student work results based on technology was an indicator that they were able to adapt more modern and authentic assessment methods. This is an important foundation for the development of a more inclusive and student-centered learning system. However, although

the results showed a positive trend, it should be noted that a small number of participants still gave low scores on several indicators. This indicated a diversity of abilities that needed to be followed up through further training, mentoring teaching practices, and strengthening critical reflection in the use of technology. Thus, the results of this study not only described the competence of ESTE students of TPE in implementing HOTS-based TPACK but also provided an important picture for curriculum designers, educators, and policymakers to continue improving the quality of teacher training through a holistic and contextual approach.

To better understand how the competencies of ESTE students of TPE are reflected in the implementation of HOTS-based TPACK, the following is an explanatory framework for each dimension or aspect. First, in terms of the use of technology and teaching aids, the majority of students showed quite good abilities. They were able to use technology effectively to support the learning process, both to compile materials and utilize visual media. However, a small number of students experienced difficulties, especially in assessing the effectiveness of technology and linking it to the learning process optimally. This condition indicated the need for additional training and more adequate technical support to help those who still faced challenges in this aspect. This reflected the mastery of TK as stated by (Mishra & Koehler, 2006) stating that teachers need to understand how technology works and how to use it in learning. This is also in line with the view of (Souza et al., 2024) regarding the need for technological pedagogical reasoning, where teachers must be able to assess the relevance and effectiveness of technology to achieve complex learning goals, including the development of HOTS.

Furthermore, in terms of PK, most students felt confident in their ability to prepare appropriate assessments, manage classes, choose effective learning strategies, and design learning methods. However, some teachers still had difficulty preparing learning steps systematically and in line with learning objectives. This indicated the need to strengthen pedagogical competence through continuous training and increased practical experience. This is in line with the framework proposed by (S. Lee, 1987) that emphasizes the importance of pedagogical reasoning and action in creating effective learning experiences. On the other hand, the difficulty of some students in preparing learning steps systematically and in line with learning objectives indicated the need to strengthen pedagogical content development, which is also supported by Donald Schön's reflective practice theory (1983) stating that teachers need to continue to reflect on their practices to improve the quality of teaching (Aleksandra K. et al., 2022).

In the CK aspect, the participants showed good mastery of the teaching material, problem-solving skills, use of various forms of assessment, and evaluation of student understanding. This indicated that ESTE students of TPE had a strong knowledge base to support effective learning. However, due to the importance of developing students' high-order thinking skills, continuous improvement in content mastery remained the main focus in teacher professional development. Shulman's (1986) theory is again relevant in this dimension in terms of content mastery which becomes the main foundation of a teacher's competence (Sutamrin et al., 2022). In addition, this ability is important in encouraging students' HOTS, in line with the revision of Bloom's Taxonomy by Anderson and Krathwohl which emphasizes the importance of in-depth knowledge to encourage analytical, evaluation, and creative skills in learning (Krathwohl & Anderson, 2010).

In the TCK dimension, the results showed that most students were able to integrate technology into learning content and design teaching tools such as lesson plans that support the development of student creativity. However, there were still some obstacles in preparing technology-based materials, thus indicating the importance of more practical technology training and the availability of access to digital resources. This ability is in line with the TCK framework which emphasizes the importance of understanding how content representation changes when technology is used (Krauss et al., 2008). However, there were still obstacles in preparing technology-based materials, indicating the importance of more applicable training. Lave and Wenger's (1991) Situated Learning Theory can also be the basis, that learning and

training must be contextual and based on real experiences so that teachers can deeply understand the integration of technology and content (McDermott, 2010).

In the TPK aspect, most students felt quite capable of designing learning materials, choosing teaching strategies, and compiling lesson plans that support students' learning creativity. However, challenges such as difficulties in designing appropriate learning stages or methods still emerged. This indicated the need for continuous professional training and reflection so that teachers can design more relevant and meaningful learning for students. According to (Mishra & Koehler, 2006), TPK requires teachers to understand how the use of technology changes pedagogical approaches. Challenges such as compiling learning stages or choosing appropriate methods indicated the importance of reflective teaching, as explained by Perkowska-Klejman (2021) and the TPACK Developmental Model approach proposed by (Niess, 2005) which suggests gradual development from technical understanding to integration of practice.

In the last aspect, overall, the results of the TPACK analysis showed that the majority of students had good integrative abilities in combining technology, pedagogy, and learning content. They were able to choose the right technology, combine it with appropriate learning methods, and evaluate the technology-based learning process. The application of TPACK is related to the integration of technology in the learning process, which not only includes the use of technology tools and platforms but also a deep understanding of how to combine this technology with effective learning strategies (Herwanto et al., 2024). For ESTE students of TPE, mastery of TPACK is important so that they can design and implement learning that is relevant to the needs of the 21st century. With TPACK skills, ESTE students of TPE can create interactive, innovative, and meaningful learning experiences for elementary school students.

Although only a small number of participants showed limitations in certain aspects such as assessing student work or technology-method integration, these areas still need further attention. Strengthening this aspect can support the readiness of prospective teachers to face the challenges of today's education which increasingly relies on technology. This is a real implementation of the TPACK Framework developed by (Mishra & Koehler, 2006) as a conceptual framework for understanding the knowledge needed by teachers in the digital era. Although only a small number of participants showed limitations in certain aspects such as assessing student work or technology-method integration, these areas still need further attention. Strengthening this aspect is important so that prospective teachers are ready to face the challenges of the 21st century, which demands technology-based learning and is oriented toward critical and creative thinking skills. This finding emphasizes the importance of continuous professional development for ESTE students of TPE so that they can strengthen their capacity to integrate technology, pedagogical strategies, and content mastery harmoniously, to create more effective, innovative, and contextual learning according to the needs of the times.

6. Conclusion

Based on the research results, the HOTS-based CK ability of students is classified as very good. Most students showed high content mastery, marked by 53.7% (882 people) stating that they were very capable of solving various questions from the subject content and 42.5% (698 people) stating that they were capable. In terms of developing problem-solving from low to high cognitive levels, 47.8% (786 people) were in the very capable category, and 47.1% (774 people) were capable. Meanwhile, in terms of evaluating student understanding, 55.3% (909 people) stated that they were very capable of doing it. Overall, more than 90% of participants were in the capable and very capable categories in these indicators, indicating that students had a strong mastery of the teaching material and were able to develop it into a learning process that required HOTS.

Students' HOTS-based PK abilities generally showed very good results, especially in the aspects of assessment and classroom management. As many as 59.3% (975 people) of students stated that they were very capable of compiling assessment forms that were in line with the

characteristics of the learning materials, and 37.3% (614 people) felt quite capable. In terms of classroom management, 69.2% (1137 people) stated that they were very capable of creating a conducive learning atmosphere, and 28.5% (468 people) stated that they were capable. The ability to choose appropriate learning strategies was also high, with 66.5% (1094 people) of participants stating that they were very capable. However, challenges were still found in the aspect of compiling learning steps, where only 49.0% (805 people) felt very capable, while 11.8% (194 people) and 9.6% (158 people) stated that they were less capable. This shows that although students' pedagogical competence is generally high, further strengthening is needed in the aspect of systematic and HOTS-based learning planning.

Students' HOTS-based TK abilities showed a very positive tendency. Most students were able to utilize technology in the learning process, with 76.2% (1252 people) stating that they were very capable of using appropriate technology. In addition, 69.7% (1146 people) were very capable of choosing teaching aids, and 68.9% (1132 people) were very capable of adapting them to learning activities. The ability to choose software that is relevant to the teaching material is also quite high, with 61.0% (1003 people) in the very capable category. However, there are still challenges in the evaluative aspect, where 16.9% (278 people) stated that they had difficulty evaluating the software used, and 8.5% (139 people) even stated that they had great difficulty. In addition, 22.3% (184 people) admitted that they had great difficulty in connecting the function of technology with the learning process effectively. These findings indicate that although students were quite reliable in selecting and using learning technology, they still needed assistance to improve their reflective and critical skills in evaluating and optimally integrating technology into the HOTS-based learning process.

Students' HOTS-based TPACK abilities showed very good results. The majority of the participants were able to integrate technology, pedagogy, and content effectively in learning. As many as 62.8% (1033 people) stated that they were very capable of assessing student work results using the HOTS approach, and 58.9% (969 people) were very capable of choosing the right media, teaching aids, and learning applications. In addition, 53.6% (888 people) were very capable of connecting technology with teaching content, and 52.4% (870 people) were very capable of evaluating technology-based learning. The ability to integrate technology with teaching methods was also quite high, with 46.3% (761 people) stating that they were very capable, although there were still 11.9% (199 people) who admitted to having difficulties in this aspect. Overall, these findings reflect that most students had high integrative abilities in utilizing TPACK to support HOTS-based learning. However, around 10–12% of students still needed reinforcement in terms of integrating technology with pedagogical strategies more effectively and reflectively.

The study highlights the importance of refining teacher education programs to provide more hands-on training in the critical evaluation and integration of technology in pedagogical practice. Emphasis should be placed on developing systematic, HOTS-oriented lesson planning and improving teachers' ability to make informed decisions about digital tools. Strengthening these competencies is essential to ensure that future educators can design and implement learning experiences that meet the complex cognitive demands of 21st-century education and effectively utilize technology to foster students' higher-order thinking skills.

Limitation

This study has several limitations that should be acknowledged. First, the data were collected through a self-assessment instrument, which may introduce subjective bias as it reflects participants' perceptions of their competencies without objective verification through observation or third-party evaluation. Second, the descriptive quantitative approach employed does not allow for causal analysis or in-depth exploration of the factors influencing the mastery of HOTS-based TPACK. Third, the focus of the study is limited to internal aspects of the participants, without considering external factors such as educational policies, available

infrastructure, and school context, which may significantly influence the implementation of TPACK in real classroom settings.

Recommendation

In response to the limitations identified in this study, several recommendations can be made to enhance future research and practice. First, to address the limitation of self-assessment bias, future studies should incorporate more objective measures of competence, such as classroom observations, performance-based assessments, or third-party evaluations, to validate participants' self-reported data. Second, to overcome the limitations of the descriptive quantitative approach, future research should employ mixed-methods or experimental designs to explore causal relationships and gain deeper insights into the factors influencing the development of HOTS-based TPACK. Third, considering that this study focused only on internal participant factors, future investigations should also examine external influences, such as institutional support, infrastructure availability, school culture, and national education policies, to provide a more comprehensive understanding of the implementation of TPACK in real classroom settings. Furthermore, practical interventions should be developed to address identified weaknesses, particularly in the evaluation and integration of technology. This includes targeted training, continuous mentoring, and professional development initiatives such as workshops or learning clinics that not only enhance technical skills but also promote reflective and sustainable pedagogical practices aligned with 21st-century learning goals.

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Conflict of Interest

The authors have no conflict of interest in conducting research and article publication.

Declaration of Generative AI-assisted Technologies

This manuscript was prepared without the assistance of Generative AI. All intellectual contributions, critical analyses, and final revisions were conducted by the authors. The authors take full responsibility for the accuracy, originality, and integrity of the content presented in this work.

References

Aleksandra K., J., J., & S., B. (2022). Teachers' beliefs about teaching and encouraging reflexivity in teaching practices. *Journal of Educational Sciences*, *46*(1), 3–13. https://doi.org/10.35923/jes.2022.2.01

Almerich, G., Gargallo-Jaquotot, P., & Suárez-Rodríguez, J. (2024). ICT integration by teachers: A basic model of ICT use, pedagogical beliefs, and personal and contextual factors. *Teaching and Teacher Education*, *145*(June 2024), 104617. https://doi.org/10.1016/j.tate.2024.104617

Chang, C. F., Annisa, N., & Chen, K. Z. (2024). Pre-service teacher professional education program (TPE) and Indonesian science teachers' TPACK development: A career-path comparative study. *Education and Information Technologies*, *30*(7), 8689–8711.

https://doi.org/10.1007/s10639-024-13160-6

Deng, Z. (2018). Pedagogical content knowledge reconceived: Bringing curriculum thinking into the conversation on teachers' content knowledge. *Teaching and Teacher Education*, *72*, 155–164. https://doi.org/10.1016/j.tate.2017.11.021

Fakhriyah, F., Masfuah, S., Hilyana, F. S., & Mamat, N. (2022). Analysis of Technological Pedagogical Content Knowledge (Tpack) Ability Based on Science Literacy for Pre-Service Primary School Teachers in Learning Science Concepts. *Jurnal Pendidikan IPA Indonesia*, *11*(3), 399–411. https://doi.org/10.15294/jpii.v11i3.37305

Falloon, G. (2020). From digital literacy to digital competence: the teacher digital competency (TDC) framework. *Educational Technology Research and Development*, *68*(5), 2449–2472. https://doi.org/10.1007/s11423-020-09767-4

Haleem, A., Javaid, M., Qadri, M. A., & Suman, R. (2022). Understanding the role of digital technologies in education: A review. *Sustainable Operations and Computers*, *3*(May), 275–285. https://doi.org/10.1016/j.susoc.2022.05.004

Herwanto, A., Wati, U. A., & Senen, A. (2024). *Application of TPACK for Student Learning Motivation in Science Subjects d in Elementary School*. *11*(2), 455–473. https://doi.org/10.53400/mimbar-sd.v11i2.71840

Isrokatun, I., Sunaengsih, C., Aah, M., Syahid, A., & Amelia, D. (2024). *HOTS-Based Learning Versus HOTS-Based Test Instruments : A Study Analysis of Elementary School Teachers ' and Students ' Readiness*. *11*(3), 595–612. https://doi.org/10.53400/mimbar-sd.v11i3.75404

Jaenudin, R., Chotimah, U., Farida, F., & Syarifuddin, S. (2020). Student Development Zone: Higher Order Thinking Skills (Hots) in Critical Thinking Orientation. *International Journal of Multicultural and Multireligious Understanding*, *7*(9), 11. https://doi.org/10.18415/ijmmu.v7i9.1884

Krathwohl, D. R., & Anderson, L. W. (2010). Merlin C. Wittrock and the revision of bloom's taxonomy. *Educational Psychologist*, *45*(1), 64–65. https://doi.org/10.1080/00461520903433562

Krauss, S., Brunner, M., Kunter, M., Baumert, J., Blum, W., Neubrand, M., & Jordan, A. (2008). Pedagogical Content Knowledge and Content Knowledge of Secondary Mathematics Teachers. *Journal of Educational Psychology*, *100*(3), 716–725. https://doi.org/10.1037/0022-0663.100.3.716

Kristiawan, M., & Muhaimin. (2019). Indonesian teacher competencies in digital. *International Journal of Educational Review*, *1*(2), 56–61. https://doi.org/10.33369/ijer.v1i2.8846

Lee, J., & Paul, N. (2023). A Review of Pedagogical Approaches for Improved Engagement and Learning Outcomes in Mathematics. *Journal of Student Research*, *12*(3), 1–9. https://doi.org/10.47611/jsrhs.v12i3.5021

Lee, K. S. (2014). Pre-Service Teachers' Technological Pedagogical Knowledge: A Continuum of Views on Effective Technology Integration. *International Journal of E-Learning & Distance Education*, *29*(292), 1–18. https://doi.org/10.1007/s10639-024-13160-6

Lee, S. (1987). Knowledge and teaching: Foundations of the New Reform. In *Harvard Educational Review* (Vol. 57, Issue 1, pp. 1–21). https://people.ucsc.edu/~ktellez/shulman.pdf

Letchumanan, M., Husain, S. S., Mohd Ayub, A. F., Kamaruddin, R., & Zulkifli, N. N. (2022).

Migrating to Technology Integrated Classes to Promote Higher Order Thinking Skills among University Students: Perspectives from Mathematics Academicians. Malaysian Journal of Mathematical Sciences, 16(4), 749–769. https://doi.org/10.47836/mjms.16.4.08

Letchumanan, M., Said Husain, S. K., Mohd Ayub, A. F., Kamaruddin, R., & Zulkifli, N. N. (2023). Determining the Factors that Promote Higher Order Thinking Skills in Mathematics Technology Enhanced Learning Environment: Perspective from University Students. Malaysian Journal of Mathematical Sciences, 17(1), 13–23. https://doi.org/10.47836/mjms.17.1.02

Ludwikowska, K. (2019). Teacher competence inventory: An empirical study on future-oriented competences of the teaching profession in higher education in India. *Education and Training*, *61*(9), 1123–1137. https://doi.org/10.1108/ET-12-2018-0266

Mahrani, M., Maruf, M., Hartono, H., & Nurlina, N. (2023). Development of TPACK-Oriented Teaching Materials Assisted by Google Sites in Science Learning for Elementary Schools. *European Online Journal of Natural and Social Sciences*, *12*(4), 360–374. https://european-science.com/eojnss/article/view/6827

Manaff, N. A., & Azahari, M. H. (2024). Digital Technology's Effect On Teaching And Learning. *International Journal of Research in Education Humanities and Commerce*, *05*(02), 129–135. https://doi.org/10.37602/IJREHC.2024.5211

Mayer, R. E. (2014). Incorporating motivation into multimedia learning. *Learning and Instruction*, *29*, 171–173. https://doi.org/10.1016/j.learninstruc.2013.04.003

Maiza, M., Amanah, F. P., & Nafiah, H. (2024). Developing hots-based e-module to improve students' reading skill at satu nusa lampung university. Journal of English Teaching, Applied Linguistics and Literatures, *7*(2), 161. https://doi.org/10.20527/jetall.v7i2.20663

McDermott, R. P. (2010). The acquisition of a child by a learning disability. In *Understanding Practice* (pp. 269–305). https://doi.org/10.1017/cbo9780511625510.011

Mishra, P., & Koehler, M. J. (2006). Technological Pedagogical Content Knowledge: A Framework for Teacher Knowledge. *Teachers College Record: The Voice of Scholarship in Education*, *108*(6), 1017–1054. https://doi.org/10.1177/016146810610800610

Musi, I. (2023). HOTS-Oriented Thematic RPP Learning : Increasing the Independence of Elementary School Students. *Thinking Skills and Creativity Journal*, *6*(2), 168–175. https://doi.org/10.23887/tscj.v6i2.69948%250

Nanola, N., Maftuh, B., Wulida, Y., & Siregar, S. W. (2024). *TPACK Learning in Improving Teacher Skills in Elementary School : A Systematic Literature Review*. *11*(2), 422–440. https://doi.org/10.53400/mimbar-sd.v11i2.71832

Niess, M. L. (2005). Preparing teachers to teach science and mathematics with technology: Developing a technology pedagogical content knowledge. *Teaching and Teacher Education*, *21*(5), 509–523. https://doi.org/10.1016/j.tate.2005.03.006

Ning, Y., Zhang, C., Xu, B., Zhou, Y., & Wijaya, T. T. (2024). Teachers' AI-TPACK: Exploring the Relationship between Knowledge Elements. *Sustainability (Switzerland)*, *16*(3). https://doi.org/10.3390/su16030978

Perkowska-Klejman, A. (2021). Reflective Learning as a Response to Contemporary Educational Challenges. *Lubelski Rocznik Pedagogiczny*, *40*(3), 7–23. https://doi.org/10.17951/lrp.2021.40.3.7-23

Pokhrel, S. (2024). Digital Technologies in Physics Education: Exploring Practices and Challenges. *Teacher Education Advancement Network Journal*, *15*(1), 37–48. http://scioteca.caf.com/bitstream/handle/123456789/1091/RED2017-Eng-8ene.pdf?sequence=12&isAllowed=y%0Ahttp://dx.doi.org/10.1016/j.regsciurbeco.2008.06.005%0Ahttps://www.researchgate.net/publication/305320484_SISTEM_PEMBETUNGAN_TERPUSAT_STRATEGI_MELESTARI

Pollock, J. E., & Tolone, L. J. (2020). Improving student learning one teacher at a time. ASCD. http://www.ascd.org

Practice, T., & Bloom, R. (2008). A Revision of Bloom ' s Taxonomy : An Overview David R . Krathwohl. *ReVision*, *41*(4), 212–218. https://www.jstor.org/stable/1477405

Ragil, I., Atmojo, W., Saputri, D. Y., & Fajri, A. K. (2022). *Analysis of STEAM-Based TPACK Integrated Activities in Elementary School Thematic Books*. *9*(2), 317–335. https://doi.org/10.53400/mimbar-sd.v9i2.49131

Rahayu, A. H., Widodo, A., & Saud, U. S. (2024). *Improving Technological Pedagogical Content Knowledge (TPACK) of Elementary School Teachers through Training with a Collaborative , Practical and Reflective Approach*. *11*(4), 642–658. https://doi.org/10.53400/mimbar-sd.v11i4.78644

Rati, N. W., Arnyana, I. B. P., Dantes, G. R., & Dantes, N. (2023). HOTS-Oriented e-Project-Based Learning: Improving 4C Skills and Science Learning Outcome of Elementary School Students. *International Journal of Information and Education Technology*, *13*(6), 959–968. https://doi.org/10.18178/ijiet.2023.13.6.1892

Rokhman, F., Purnomo, A., Yuwono, A., Saputro, I. H., Plangsorn, B., & Habibi, A. F. (2024). Sustainable ecosystem for professional teachers in Indonesia: The role of teacher professional education programs in achieving the SDGs. *E3S Web of Conferences*, *568*, 1–8. https://doi.org/10.1051/e3sconf/202456804033

Sailer, M., Schultz-Pernice, F., & Fischer, F. (2021). Contextual facilitators for learning activities involving technology in higher education: The C♭-model. *Computers in Human Behavior*, *121*(October 2020), 106794. https://doi.org/10.1016/j.chb.2021.106794

Saptani, E., Rukmana, A., & Supriyadi, T. (2024). *Analysis of TPACK Competence of Elementary School Physical Education Teachers : A Cross-Sectional Study*. *11*(4), 702–721. https://doi.org/10.53400/mimbar-sd.v11i4.78743

Sidiq, Y., Ishartono, N., Desstya, A., Prayitno, H. J., Anif, S., & Hidayat, M. L. (2021). Improving elementary school students' critical thinking skill in science through hots-based science questions: A quasi-experimental study. *Jurnal Pendidikan IPA Indonesia*, *10*(3), 378–386. https://doi.org/10.15294/JPII.V10I3.30891

Sidel, J. L., Bleibaum, R. N., & Tao, K. C. (2018). Quantitative descriptive analysis. Descriptive analysis in sensory evaluation, 287-318.

Souza, A. A. De, Alvez, I. da C., Sousa, L. M. da S., & Silva, J. M. da. (2024). The Indispensability of the Educational Planning Process. *The Indispensability of the Educational Planning Process*, *05*(01), 170–182. https://doi.org/10.51249/gei.v5i01.1862

Spante, M., Hashemi, S. S., Lundin, M., & Algers, A. (2018). Digital competence and digital literacy in higher education research: Systematic review of concept use. *Cogent Education*, *5*(1), 1–21. https://doi.org/10.1080/2331186X.2018.1519143

Sun, H., Xie, Y., & Lavonen, J. (2022). Effects of the use of ICT in schools on students' science

higher-order thinking skills: comparative study of China and Finland. 1–18. https://doi.org/10.1080/02635143.2022.2116421

Susantini, E., Isnawati, & Raharjo. (2022). HOTS-Link Mobile Learning Application: Enabling Biology Pre-service Teachers to Devise HOTS-Based Lesson Plans. Journal of Science Education and Technology, 31(6), 783-794. https://doi.org/10.1007/s10956-022-09993-w

Sutamrin, S., Rosidah, R., & Zaki, A. (2022). The Pedagogical Content Knowledge (PCK) of Prospective Teachers. *EduLine: Journal of Education and Learning Innovation*, *2*(4), 399–405. https://doi.org/10.35877/454ri.eduline1291

Syafryadin, Wardhana, D. E., Noermanzah, Rofi'i, A., & Awalludin. (2021). Students' perspective and problems in implementing higher order thinking skill (HOTS) in speaking for presentation class. *Journal of Language and Linguistic Studies*, *18*(1), 477–487. https://doi.org/10.52462/jlls.196

Symeonidis, V. (2019). Teacher competence frameworks in Hungary: A case study on the continuum of teacher learning. *European Journal of Education*, *2019*, 400–412. https://doi.org/10.1111/ejed.12347

Tanak, A. (2020). Designing tpack-based course for preparing student teachers to teach science with technological pedagogical content knowledge. *Kasetsart Journal of Social Sciences*, *41*(1), 53–59. https://doi.org/10.1016/j.kjss.2018.07.012

Taopan, L. L., Drajati, N. A., & Sumardi. (2020). Tpack Framework: Challenges and Opportunities in Efl Classrooms. *Research and Innovation in Language Learning*, *3*(1), 1–22. https://doi.org/10.33603/rill.v3i1.2763

Tomlinson, C. A. (2011). *Differentiate instruction in mixed-ability classrooms*. https://d1wqtxts1xzle7.cloudfront.net/44098361/Carol_Ann_Tomlinson_How_to_Differentiate_InstrucBookSee.org-with-cover-page-v2.pdf?Expires=1631251576&Signature=YZi5pSld61OpLx2~tuG4isXixDt0Sg9yLDjEz0yeUm1X~y576UCjpIlUsfAzAEMlyH2OtfXM~95owzfu8j8R6kQCZ3v6IE

Tyas, E. H., & Naibaho, L. (2021). Hots Learning Model Improves the Quality of Education. *International Journal of Research -GRANTHAALAYAH*, *9*(1), 176–182. https://doi.org/10.29121/granthaalayah.v9.i1.2021.3100

Vignare, K., & Lorenzo, G. (2020). Improving Critical Courses Using Digital Learning & Pedagogy A Guide for Academic Administrators. *Joint Publication of Association of Public and Land-Grant Universities and Every Learner Everywhere*. https://www.everylearnereverywhere.org/resources/improving-critical-courses-using-digital-learning-evidence-based-pedagogy/

Vygotsky, L. S. (2019). *Mind in Society: Development of Higher Psychological Processes*. Harvard University Press. https://doi.org/https://doi.org/10.2307/j.ctvjf9vz4

Wakhidah, N., & Lodhi, S. S. (2025). Measuring TPACK and HOTS of Teacher Professional Education Students Based on Lesson Plans. *Journal of Innovation in Educational and Cultural Research*, *6*(2), 267–276. https://doi.org/10.46843/jiecr.v6i2.1796

Wibowo, F. (2022). Effcts of Augmated Realiti Intrgration based Model Selef-Directed Learning. *Journal of Technology and Science Education*, *4*(4), 215–227. http://www.jotse.org/index.php/jotse/article/view/110/142

Wiggins, G. (1999). Understanding by design. *Choice Reviews Online*, *36*(09), 36-52. https://doi.org/10.5860/choice.36-5230

Yan, D. (2023). Visible learning: the sequel: a synthesis of over 2,100 meta-analyses relating to achievement Visible learning: the sequel: a synthesis of over 2,100 meta-analyses relating to achievement , by John Hattie, Abingdon, Routledge, 2023, 510 pp., £18.39 (pbk). *Teacher Development*, *27*(5), 664–667. https://doi.org/10.1080/13664530.2023.2237484

Yanuarto, W. N., Anggoro, S., & Suanto, E. (2025). *ICT Literacy , TPACK , and HOTS in Learning Quality of Indonesian Higher Educational System : Structural Model*. *23*, 1155–1169. https://doi.org/10.57239/PJLSS-2025-23.1.0090