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Integrating Primary School Teacher Education Students' TPACK Competence in Developing C6-Level HOTS Questions

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ABSTRACT

Objective: This study aims to analyze the ability of students in the Primary School Teacher Education program to integrate Technological Pedagogical Content Knowledge (TPACK) in developing mathematics questions based on Higher-Order Thinking Skills (HOTS) at the C6 level (creating). This competence is essential for preparing future teachers to design questions that foster creativity, problem-solving, and innovation among primary school students. **Method:** This research employed a qualitative descriptive approach involving final-semester students who had completed courses on instructional design and TPACK. Data were collected through documentation of C6-level HOTS question development assignments, semi-structured interviews, and classroom observations. Data were analyzed through data reduction, display, and conclusion drawing. **Results:** The findings indicate that most students demonstrated the ability to integrate TPACK components—content, pedagogy, and technology—in designing HOTS-based mathematics questions at the C6 level. While some questions reflected strong alignment with C6 indicators such as originality and contextual relevance, challenges remain in harmonizing all TPACK dimensions consistently. Variability in technological integration and depth of creativity was also observed. **Novelty:** This study offers insight into how TPACK competencies support the development of C6-level HOTS questions within primary mathematics education. It contributes to existing literature by linking TPACK directly with cognitive assessment design in teacher education and highlighting the preparedness of pre-service teachers to meet the demands of 21st-century learning.

INTRODUCTION

The rapid advancement of the digital era has profoundly transformed the educational landscape, demanding continuous innovation and adaptation at all levels of schooling (Mukul & Büyüközkan, 2023). Educational transformation is no longer limited to the integration of digital tools but now emphasizes the cultivation of Higher-Order Thinking Skills (HOTS), which are essential for preparing students to navigate real-world challenges (Miterianifa et al., 2021). Twenty-first-century learning underscores the importance of mastering the 4Cs, critical thinking, creativity, communication, and collaboration, where HOTS serves as a central framework for cognitive development (Zainil et al., 2023). In the context of primary education, HOTS becomes a foundational pillar in helping students solve authentic problems, apply learned concepts, and engage in reflective thinking from an early age (Karmila et al., 2023).

A crucial aspect of HOTS-based instruction lies in a teacher's ability to construct assessment items that challenge students' cognitive abilities beyond memorization (Azid et al., 2022). According to the revised Bloom's Taxonomy, level C6 (creating) is the highest cognitive domain, involving skills such as designing, constructing, or formulating original products or ideas (He et al., 2025; Özpir et al., 2025). However, many pre-service and in-service teachers struggle to develop mathematics questions that align with this level. Specific difficulties include: (1) translating abstract learning objectives into concrete assessment tasks, (2) limited exposure to open-ended question formats, (3) overreliance

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on procedural or factual question types, and (4) reluctance to integrate interdisciplinary or real-world contexts that stimulate student creativity. Moreover, a lack of confidence, insufficient training, and minimal feedback in early teacher education further hinder pre-service teachers from designing tasks that stimulate C6-level thinking (Eyadat et al., 2025).

Simultaneously, the digital era presents considerable opportunities to enhance assessment practices through meaningful technology integration. The Technological Pedagogical Content Knowledge (TPACK) framework, developed by Mishra and Koehler, outlines the intersection of three key domains, content (CK), pedagogy (PK), and technology (TK), that must be synergized to create effective and innovative teaching practices (Arifuddin et al., 2025). eachers with strong TPACK competencies are expected to design learning experiences that are not only pedagogically sound and content-accurate but also enriched by the strategic use of technology to deepen student understanding and engagement (Koh, 2016).

Several studies have focused on developing TPACK competencies among pre-service teachers, especially in the domains of instructional media creation and lesson planning (Nisa' & Faroh, 2021; Satriawati et al., 2022). However, few have examined how TPACK is operationalized specifically in the design of cognitively demanding assessment tasks—particularly mathematics questions targeting HOTS at the C6 level. While some research has explored TPACK's role in promoting problem-solving or analytical thinking (B & Malik, 2024; Su, 2023). limited studies critically investigate how TPACK components intersect with HOTS principles in the context of question development. As a result, TPACK and HOTS are often treated as separate innovations rather than interrelated frameworks for instructional design.

This reveals a crucial gap in both theory and practice. Empirical evidence on how pre-service teachers apply TPACK in assessment design, especially in formulating questions that engage students in the creative process, is still scarce (Chai et al., 2019). Consequently, many teacher education programs have not yet equipped candidates with the skills to design assessments that harmoniously integrate content understanding, effective pedagogy, and appropriate digital tools (Nugroho Yanuarto et al., 2021; Wahyu et al., 2024). This study seeks to fill that gap by investigating how pre-service elementary school teachers integrate TPACK in the development of C6-level HOTS mathematics questions.

Preliminary observations among pre-service teacher candidates in the Primary School Teacher Education program indicate a reliance on lower-order cognitive questions—such as recalling facts (C1), interpreting basic concepts (C2), or applying routine procedures (C3), with limited integration of digital tools or authentic contexts. This suggests a lack of experience and confidence in designing assessment tasks that demand creativity, innovation, and higher-order thinking (Ishartono et al., 2023). Thus, further investigation is needed to determine how well TPACK competencies support the construction of HOTS-based mathematics questions among these future educators.

Elementary mathematics education demands an approach that is contextual, creative, and cognitively stimulating. C6-level HOTS questions have the potential to promote deeper thinking, foster the integration of multiple mathematical concepts, and elicit open-ended, reflective responses from students (Rohmawati & Fathoni, 2022). In this context, pre-service elementary school teachers must be capable of designing assessments

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that go beyond recall and encourage the development of original ideas (Nur et al., 2020). If these future teachers master TPACK, they will be better prepared to align their assessments with the demands of the curriculum and the profile of 21st-century learners. In essence, TPACK mastery is a key factor in enhancing the planning and implementation of HOTS-based mathematics instruction (Saputri et al., 2025).

Therefore, this study aims to analyze the extent to which pre-service primary school teachers are able to integrate TPACK elements in developing mathematics questions aligned with C6-level HOTS. By focusing on the intersection of content, pedagogy, and technology in assessment design, this research contributes to the evolving discourse on 21st-century teacher preparation and offers practical insights into curriculum enhancement for teacher education programs. The synergistic interplay of these three domains enables the creation of assessment items that are not only conceptually accurate and pedagogically appropriate but also enhanced by technology to foster creativity and contextual relevance. For instance, instead of prompting students to simply define "perimeter," one observed pre-service teacher could have challenged them to design a garden with specific perimeter and area constraints using digital tools. Such findings underscore the practical challenges pre-service teachers face in designing cognitively complex tasks, and highlight the need for integrated training that explicitly links TPACK with C6-level assessment development.

RESEARCH METHOD

This study employed a qualitative descriptive design to explore how pre-service elementary school teachers integrate Technological Pedagogical Content Knowledge (TPACK) in developing Higher Order Thinking Skills (HOTS) questions at the C6 level (creating) within mathematics learning. The research focused on three main aspects: the process of designing questions, the quality of the items produced, and the extent to which TPACK components were reflected in both the product and the process of question development.

Participants were selected using purposive sampling, specifically targeting final-semester students in the Primary School Teacher Education (PGSD) program at a public university in Indonesia. To ensure relevant experience and preparedness, the inclusion criteria consisted of: (1) completion of coursework in mathematics teaching, learning media development, and educational technology; (2) active participation in a final course project requiring the design of HOTS-based mathematics questions; and (3) a minimum cumulative GPA of 3.25, along with documented involvement in teaching practicums or school-based learning activities. These criteria were established to ensure that participants had both the theoretical foundation and practical exposure necessary to meaningfully integrate TPACK in assessment design.

Data were collected through three techniques: documentation analysis, classroom observation, and semi-structured interviews. The documentation involved collecting students' assignment products, which consisted of original mathematics questions designed to reach the C6 level of Bloom's taxonomy. Each student submitted at least three questions, complete with contextual descriptions and integration of technological tools. Observations were conducted throughout the task development process using a structured observation sheet to capture specific indicators of TPACK integration, including how students generated ideas, chose pedagogical approaches, and applied digital tools. These observations provided insight into the real-time behaviors and

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patterns in students' design processes. To complement these methods, semi-structured interviews were conducted with selected students to explore their cognitive strategies, decision-making rationales, and self-reflection in designing HOTS-based questions. Interview prompts were aligned with the seven dimensions of TPACK to reveal how students internalized and operationalized each component.

The instruments used included an observation guide, an interview protocol, and an assessment rubric. The rubric assessed the student-designed questions based on four main criteria: (1) alignment with C6-level cognitive indicators such as constructing, designing, or creating; (2) content validity and conceptual accuracy of the mathematics material; (3) pedagogical appropriateness, including clarity of instructions and student engagement potential; and (4) integration of relevant and meaningful technology to support learning. To improve readability, the detailed indicators of the TPACK components, which were initially displayed in a lengthy table, were condensed and reorganized systematically (available in Appendix A) to highlight the essential traits associated with each domain: Technological Knowledge (TK), Pedagogical Knowledge (PK), Content Knowledge (CK), and the intersections among them.

Data analysis was conducted through a three-phase qualitative approach: data reduction, data display, and conclusion drawing. The students' assessment products and interview transcripts were coded using the TPACK framework as an analytical lens. The analysis paid close attention to the cognitive sequence of question construction, the integration of TPACK domains, and the patterns of students' problem-solving and decision-making during the design process. Observation data served to triangulate findings, especially regarding how students moved between content understanding, pedagogical reasoning, and the use of technology. The coding process revealed not only the level of TPACK mastery in the final products but also how that mastery developed throughout the learning task. This comprehensive analysis enabled the researchers to construct a clear picture of how pre-service elementary school teachers apply TPACK in assessment design for mathematics learning, particularly in constructing cognitively complex, creative, and technology-integrated questions.

RESULTS AND DISCUSSION

Results

The results of the study indicate that the ability of PGSD students to develop HOTS-based mathematics questions at the C6 level with TPACK integration varies across three main aspects: the quality of the questions, the coherence of TPACK components, and the development process of the questions. The research instruments were developed based on the TPACK theoretical framework, which includes seven core components: TK (Technological Knowledge), PK (Pedagogical Knowledge), CK (Content Knowledge), TPK (Technological Pedagogical Knowledge), TCK (Technological Content Knowledge), and PCK (Pedagogical Content Knowledge). The indicators for each component were operationalized as outlined in Table 1.

Table 1. Operationalization of TPACK Components

Code	Indicator	Description
TK 1	Insights related to technology, both low-tech (paper, pencils, etc.) and digital technology (software, internet, etc.)	The subjects have a broad understanding of technology, both low-tech and digital. This is reflected in their ability to select appropriate learning media, as seen in the teaching modules they developed.

TK 2	Understanding related to the ability to use technology.	The subjects are proficient in operating technology, as demonstrated when they conducted lessons using a laptop, LCD projector, and speakers. During the teaching practice, there were no technical issues encountered. Additionally, the subjects organized their lessons using PowerPoint media and designed learning materials with the Canva application. The presentation media in PowerPoint were independently designed by the research subjects, although some content was downloaded from the internet, it was customized accordingly. By designing the media independently, the subjects found it easier to implement it in their teaching.
TK 3	Proficiency in using technology as a tool for communication, achieving objectives, and problem-solving.	The subjects demonstrate strong proficiency in using technology. This is evident in their selection of technology that is engaging and capable of enhancing student interest and motivation. The technology used aligns with current trends, as almost every school now has access to LCD projectors. Additionally, the use of technology is tailored to the learning objectives and the students' prior knowledge. The students' prior knowledge is assessed based on their ability to answer trigger questions, which are integrated with a diagnostic assessment.
PK 1	Understanding related to teaching methods and procedures.	The subject demonstrates a strong understanding of teaching methods, models, strategies, and techniques. This is evident in the variety of methods outlined in the teaching materials. The subject excels in creating teaching materials, ranging from teaching modules to assessments. The teaching modules developed are of high quality, focusing on the development of 21st-century skills, character education (PPK), and the 4Cs (creativity and innovation, critical thinking and problem solving, communication, collaboration).
PK 2	Mastery of student learning strategies, classroom management, the ability to design lessons, and the ability to conduct learning evaluations.	The subject's mastery in designing and managing learning is evident in the learning materials created and the way the subject practices teaching. The methods and steps of teaching practiced are in line with what is outlined in the teaching modules. The subject is able to manage the class well, as demonstrated by a student-centered, enjoyable, relaxed, discussion-based, and music-enhanced learning environment. The subject frequently employs a variety of teaching methods. Almost all of the subjects use lecture methods with PowerPoint media. However, this method is combined with other approaches such as games, discussions, group work, exploration, and more, making the learning process more engaging. Furthermore, the teaching models used are also varied, including Project-Based Learning (PBL), Discovery Learning, and others. In addition to varied models, methods, and strategies, the assessment techniques are also diverse. Moreover, there is a reflection activity at the end of each lesson.
CK 1	Knowledge related to the learning material, including facts, concepts, theories, and procedures.	The subject possesses knowledge related to the learning content, which is evident in the teaching materials that are rich in references and are independently developed in the teaching tools. The material presented aligns with what is written in the teaching materials. The content is delivered in a logical sequence, starting from concrete concepts to abstract ones. Furthermore, the subject also provides examples that aid in students' understanding. The subject is also able to answer questions related to the teaching material. Additionally, the subject often asks HOTS-related questions that encourage

		students to engage in higher-order thinking and support the development of 21st-century skills.
TPK 1	Awareness of the shift in strategies and learning procedures due to the use of technology.	Educational technology is effectively used to support the methods and strategies applied in teaching. PowerPoint presentations and educational videos displayed on the LCD projector serve as aids for the teacher in delivering material through lecture, question-and-answer, and discussion methods. The subject also utilizes a speaker as an audio amplifier for the educational videos being played.
TCK 1	Knowledge related to the use of technology to create new representations of learning material and assist students in understanding the material.	The selection of technology used is relevant to the material being taught. Through the assistance of the technology employed, students' understanding can be enhanced. Additionally, there are subjects that utilize Quizizz in the learning process. This helps develop student activities and assignments that involve the use of technology.
TCK 2	Insight related to how to choose the best technology that can be used to achieve learning objectives.	The selection of technology is aimed at facilitating students' understanding of the material. The subject uses PowerPoint presentations to help students grasp the content more easily. Additionally, the use of video as a learning medium allows students to engage more relaxedly, thus enhancing their comprehension of the subject matter. The subject also designs instructional materials in an engaging manner using Canva, which helps stimulate students' interest and motivation to learn.
TCK 3	The understanding related to the effectiveness of technology usage in relation to the learning material and vice versa.	The effectiveness of selecting technology to deliver content is also considered in the learning process. This is evident in the use of PowerPoint, videos, and tangible media, all of which help students understand the material better. Additionally, there are instances where Quizizz is used in the learning process, which helps develop student activities and assignments.
PCK 1	Understanding related to the strategy for developing learning through the integration of learning content and pedagogy.	The selection of learning approaches and strategies by the subject aligns with the characteristics of the students and the nature of the mathematics content being taught. The demonstration method is frequently used, especially in lower-grade classes, as it is in line with the developmental stage of students, who are still at the concrete operational phase and thus require realistic practice. Additionally, the assessment questions used are appropriate for measuring students' understanding of the material being taught.

Based on the qualitative data analysis, it can be concluded that the students have a strong command over all components of TPACK (Technological, Pedagogical, and Content Knowledge). They are able to effectively utilize technology to support learning (TK), demonstrate proficiency in student-centered strategies, methods, and classroom management (PK), and have a deep understanding of the content in line with the Merdeka Curriculum (CK). Furthermore, the integration of technology and pedagogy (TPK), technology and content (TCK), and pedagogy and content (PCK) is also reflected in the students' ability to design contextual, innovative, and relevant learning experiences that meet the needs of 21st-century students.

The documentation results from the data collection process conducted through observation and documentation methods on the teaching materials and teaching practices of undergraduate PGSD students. This documentation includes various authentic evidences from the students' activities in designing and implementing learning materials based on the Merdeka Curriculum. The subjects in this documentation consist of six students, each teaching in grades 1 and 4 of elementary school. The data presented aims to illustrate the extent of the students' mastery of the TPACK components in designing and implementing the learning process.

Figure 1. Class 1 learning tools.

Figure 2. Class 4 learning tools.

Figure 3. Teaching practice for grade 1 Independent Curriculum

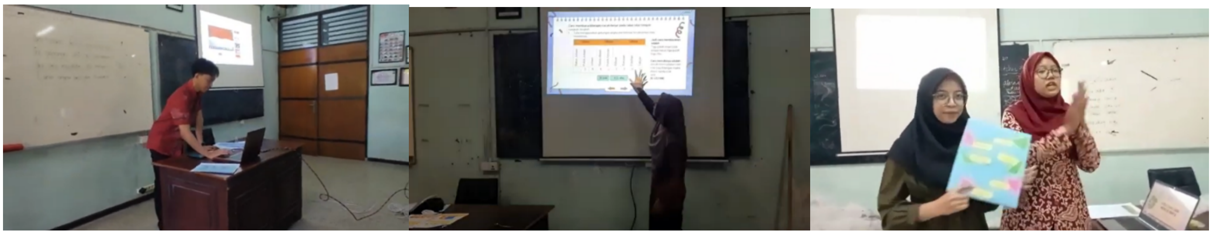

Figure 4. Teaching practice for grade 4 Independent Curriculum

The images displayed reflect the quality and creativity of the teaching materials developed by the students, such as teaching modules, digital learning media, and assessment designs that align with the Pancasila student profile. In addition, the

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documentation of teaching practices demonstrates how the students apply student-centered learning approaches, manage the classroom effectively, and utilize supporting technologies such as projectors, PowerPoint, and educational videos. Each photo serves as visual evidence of the integrated application of pedagogical, technological, and content knowledge, illustrating the students' readiness to take on the role of professional educators in the era of the Merdeka Curriculum.

Thus, the documentation of learning devices and teaching practices of S1 PGSD students provides a real picture of how TPACK competence is implemented in the context of the Merdeka Curriculum learning. Students are not only able to develop relevant and contextual teaching materials, but also demonstrate the ability to manage innovative, enjoyable, and learner-centered learning. The integration of technology, pedagogy, and content appears to be in harmony at every stage of the learning process they implement.

These findings underscore that the integration of TPACK components is not merely additive but synergistic when applied effectively in developing C6-level HOTS questions. The combination of rich content knowledge, thoughtful pedagogical strategies, and purposeful use of technology results in more meaningful, contextual, and cognitively demanding assessments. Figures 1–4 serve not just as visual documentation, but as concrete representations of how each TPACK component, particularly TPK, TCK, and PCK, was actualized in real classroom practices. This tight linkage between conceptual understanding and implementation highlights the critical role of TPACK mastery in equipping future primary school teachers to foster creativity, innovation, and higher order thinking in mathematics education.

Discussion

The findings of this research provide an in-depth overview of how prospective elementary school teacher students integrate TPACK, higher-order thinking skills (HOTS), and the C6 level of the revised Bloom's taxonomy into the design and implementation of learning. The integration of these three components reflects the students' readiness to design learning that is not only content and pedagogy-based but also innovative through the use of technology.

The integration of TPACK in the tools and learning practices of prospective elementary school teachers reflects a developing understanding of the relationship between content, pedagogy, and technology (Habibi et al., 2020; Sofwan et al., 2023). Students are able to choose digital learning media that match the characteristics of the material and the needs of the students, such as the use of interactive videos, multimedia presentations, and online learning applications (Navarrete et al., 2025)This shows that the aspect of Technological Knowledge (TK) has been gradually integrated with Content Knowledge (CK) and Pedagogical Knowledge (PK) in designing more engaging learning experiences (Arifuddin et al., 2025; Sofwan et al., 2024). However, some devices still show a dominance of conventional approaches that have not yet fully utilized the potential of digital technology optimally. Therefore, strengthening the integrative aspect of TPACK needs to be continuously enhanced through coaching and more contextual practical experiences.

Furthermore, students' ability to integrate HOTS is reflected in the formulation of learning objectives that require students to analyze, evaluate, and create (Fakhomah & Utami, 2019; Kori, 2023; Suwarma & Apriyani, 2022). In the Merdeka Curriculum learning, students are encouraged to direct their activities not only towards mastering basic concepts but also to foster critical and reflective thinking skills (Annam et al., 2024; Nasri

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et al., 2024). Some examples of questions used reflect students' analytical and evaluative abilities, such as identifying patterns, comparing information, or providing reasons for their answers (Kania et al., 2024; Safitri et al., 2024; Sola & Bundu, 2023). However, some lesson plans still focus on remembering and understanding activities, so they do not fully encourage the comprehensive development of higher-order thinking skills (Zulrafli et al., 2023). Therefore, students' conceptual understanding of HOTS needs to be accompanied by training in designing learning activities that consistently stimulate higher-order thinking processes.

In the revised Bloom's Taxonomy, level C6 (Creating) is the highest level in the cognitive domain that requires students to produce something original from the knowledge they have learned (Aprillia et al., 2023; Khoy, 2025). In the practice of teaching students, several C6 indicators are evident from assignments that require students to create simple projects, such as designing posters, composing stories, or devising solutions to real-world problems. This effort aligns with the spirit of the Merdeka Curriculum, which encourages students to become independent and creative learners (Utia et al., 2024; Widiansyah et al., 2024). Nevertheless, the implementation of level C6 is not yet uniform across all devices and practices, as there is still a dominant focus on levels C1 to C4. This indicates the need to strengthen students' abilities in designing learning objectives and activities oriented towards creation as the pinnacle of cognitive learning.

The assertion that "TPACK has been well-integrated" is supported by rubric-based analysis and specific student artifacts. For instance, students who scored "very good" on the TK and TPK indicators designed digital media using Canva that aligned with both lesson objectives and student characteristics. Likewise, classroom observations revealed that students incorporated HOTS prompts such as "create your own math story problem using daily scenarios," which directly addressed C6-level thinking. These examples substantiate the integration of technological and pedagogical knowledge in real teaching contexts. Nevertheless, the variation in performance across TCK and PCK domains suggests that further instructional support is needed to guide students in making strategic connections between content, pedagogy, and technology. This insight should inform curriculum design in teacher education by embedding iterative feedback cycles and authentic task-based assessments to reinforce the practical application of TPACK in assessment development.

Thus, the results of this study affirm that the integration of TPACK, HOTS, and C6 is an important foundation in the development of competencies for prospective elementary school teachers. These three components complement each other in shaping innovative, meaningful, and responsive learning practices to the needs of 21st-century students. These findings provide a positive direction for improving the quality of teacher education, particularly in preparing adaptive and reflective educators. Further research is recommended to explore the implementation of this concept in real field contexts, including on teachers who have been teaching, the sustainability of practices at various levels and school conditions, as well as their impact on improving student learning outcomes in inclusive contexts and with limited resources. By expanding the scope of the study, it is hoped that TPACK-based, HOTS, and creative learning strategies can continue to be developed and widely implemented.

CONCLUSION

Fundamental Finding: The integration of TPACK, HOTS, and C6 in the learning design of prospective elementary school teachers has strong potential to generate innovative, contextual, and relevant learning experiences tailored to the demands of 21st-century

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3 education. This finding highlights the importance of equipping pre-service teachers not only with conceptual understanding but also with practical competencies to design cognitively challenging instruction that promotes creativity and higher-order thinking. 2 **Implication:** It is necessary to integrate TPACK, HOTS, and C6-level thinking from the early stages of teacher education so that pre-service teachers are equipped to design creative, collaborative, and contextually relevant learning experiences aligned with the 2 Merdeka Curriculum and the Profile of Pancasila Students. **Limitation:** This research is limited to one study program and has not yet tested direct implementation in real classrooms, nor has it used quantitative instruments to assess HOTS and C6 aspects. **Future Research:** Further research is recommended to examine the real impact of integrating TPACK, HOTS, and C6 in teaching practices and its effectiveness on student learning outcomes at various elementary school levels through approaches such as Classroom Action Research (CAR).

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