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Developing a TPaCK Textbook to Support the ScaPro-PjBL Model: Preparing Pre-Service Physics Teacher Competencies in Distance Learning for SDG 4

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ABSTRACT

Objective: *To evaluates the validity and practicality of a TPaCK textbook as supporting material for the Scaffolded Product in Project-Based Learning (ScaPro-PjBL) model to train pre-service physics teachers' TPaCK competencies. This study contributes to Sustainable Development Goal 4 (SDG 4) by promoting quality education through technology-integrated and competency-based teacher preparation. The textbook supports three learning phases: essential questions, project design with timelines and checkpoints, and tutorials on subject-specific techniques.* ***Method:*** *The textbook development followed Plomp's stages of preliminary research, development/prototyping, and assessment. The textbook has five chapters on the TPaCK concept, framework, application in physics distance learning, supporting technology, and TPaCK products. Validity was assessed by three experts using the Indonesian National Agency of Education Standards (NAES) criteria for content, presentation, language, and graphics, with scores ranging from 1 to 10. Reliability was calculated using ICC(3,k) and Cronbach's Alpha. Practicality was tested through limited (21 students) and extensive (98 students) trials using questionnaires 1–4, with similar reliability analyses.* ***Results:*** *The TPaCK textbook was categorized as valid and practical. It supported students in understanding concepts, designing TPaCK-based learning products, identifying project requirements, applying technical tutorials, and developing digital learning products such as lesson plans, worksheets, videos, and formative assessments. Conceptual and procedural scaffolding improved learning processes and technology integration.* ***Novelty:*** *This textbook provides a structured scaffold for ScaPro-PjBL implementation in preparing pre-service physics teachers for distance learning. It functions as instructional support, a practice guide, and a tool for developing TPaCK competencies aligned with SDG 4.*

INTRODUCTION

TPaCK is a complex knowledge framework because it requires mastery of transformative skills. It combines three core components: content knowledge (CK), pedagogy (PK), and technology (TK) (Koehler & Mishra, 2009). The framework can support pre-service teachers in designing and implementing high-quality and effective ICT-based learning (Jiménez Sierra et al., 2023; Weidlich & Kalz, 2026). Its scope includes pre-service teachers' ability to select appropriate technological devices (hardware and software), adjust pedagogical strategies to the characteristics of the material, and adapt learning to specific educational contexts, including social aspects, resources, and content (Aslan et al., 2025; Brianza et al., 2022). TPaCK is situated, meaning that technological, pedagogical, and content knowledge must be understood and applied within a specific educational context to produce effective learning (Nguyen et al., 2025; Petko et al., 2025). Distance learning is a relevant option for addressing the needs of digital transformation in higher education and teacher preparation for 21st-century competencies, in line with the University 4.0 model and the demands of the information industry (Abdulayeva, 2024; Gümüş, 2022; Jugembayeva & Murzagaliyeva, 2024). The use of ICT in learning, including hybrid learning and digital tools, increases the effectiveness of the learning process, expands access to learning, and enables the development of 21st-century skills, which is aligned with SDG 4 (Akram et al., 2021; Anwar et al., 2025; Mat Salleh et al., 2025).

According to Mouza (2016), TPaCK can be trained in pre-service teachers through the application of learning models in specific courses with TPaCK-oriented outcomes, complemented by TPaCK enhancement principles. In this context, the strategies recommended in the SQD-Models—including the use of lecturers as role models, reflection on the role of technology, planned technology learning, collaboration between students, scaffolding authentic technology experiences, and ongoing feedback—have many similarities with the characteristics of project-based learning (PjBL), such as solving challenging problems, group investigations, answering authentic questions, describing projects, reflecting on the process, critiquing and improving work, and creating collaborative public products (de la Torre-Neches et al., 2020; Edutopia, 2014; Larmer et al., 2015; Tondeur et al., 2020). However, PjBL has not fully met the SQD recommendations, particularly in scaffolding authentic technology experiences, as indicated by reports of weaknesses in the PjBL model related to the availability of knowledge bases, tool guides, and support throughout the project (Dag & Durdu, 2017; Goldstein, 2016; A. Rahmawati et al., 2020; Rees Lewis et al., 2018; Zhang & Ma, 2023).

A combination of scaffolding approaches is needed to produce a scaffolded product (ScaPro) in PjBL, including the TPaCK textbook. Textbooks in PjBL serve not as passive reading resources but as scaffolds that guide students' thinking and work. Textbooks can trigger project themes, provide a basis for investigation, and then guide students from basic concepts to more complex tasks (Fan et al., 2025; Stoller & Myers, 2019). In this context, textbooks also function as conceptual and material scaffolding, providing clear information, structuring learning steps, and assisting teachers when direct guidance is limited (Boon et al., 2022; Puntambekar, 2022). The most important role of textbooks in PjBL is their ability to maintain a focused, systematic, and gradual learning trajectory (Qi et al., 2025). Therefore, effective textbooks must include structured content, explicit instructions, and multimodal support, including digital formats when necessary, to facilitate students' construction of knowledge, development of products, and completion of projects independently and collaboratively (Şanal et al., 2025).

The need for TPaCK textbooks in the PjBL model is particularly high, as integrated TPaCK materials are currently limited (Guo et al., 2026). TPaCK textbooks serve as essential guides for teachers and students in understanding the TPaCK framework, particularly in team-based learning, thereby supporting project effectiveness and enhancing pedagogical and technological skills (Maisarah et al., 2026). Additionally, teachers need ready-to-use materials such as rubrics, project instructions, and planning forms to facilitate PjBL implementation and minimize preparation time (Garib, 2023; Meng et al., 2023). These materials must be flexible and adaptable because project direction and student needs can change, making access to new resources crucial (Lewis et al., 2019). Overall, teachers' requests for additional resources, including project examples and practical ideas integrated with the curriculum, suggest that TPaCK textbooks must be comprehensive, adaptable, and ready-to-use for optimal PjBL implementation (Viro et al., 2020).

Current teaching materials often do not fully support the integration of TPaCK into the PjBL process, as content, pedagogy, and technology remain separate, hindering pre-service teachers from developing stable, applicable competencies (Yao & Abd Halim, 2026). Therefore, pre-service teachers need more than just TPaCK theory; they need conceptual, project-planning, and technical guidance to understand and apply each component of TPaCK in real-world contexts (Dewi et al., 2022; I. Rahmawati et al., 2026). Predesigned textbooks that act as hard scaffolds are crucial, as they can reduce task complexity, provide structure, and anticipate critical points during project implementation (Ertmer & Glazewski, 2019; Moallem & Igoe, 2020). Integrating scaffolding appropriate to the learning phases, from orientation to reflection, enables pre-service teachers to systematically navigate the PjBL flow and implement TPaCK more effectively (Dewi et al., 2022; Meng et al., 2023). Furthermore, digital and multimodal formats can expand the scaffolding's functionality, providing visual organizers, tutorials, and templates that support both independent and collaborative learning, making TPaCK textbooks essential tools for PjBL success (Meng et al., 2023; Moallem & Igoe, 2020).

The TPaCK textbook was developed as a learning tool to help pre-service physics teachers complete TPaCK projects within the ScaPro-PjBL model. The primary rationale was the need for teaching materials that not only explain concepts but also provide targeted learning support as students undertake projects. Therefore, the textbook's content was structured to align with the ScaPro-PjBL model phases, the TPaCK mastery stages, the types of scaffolding, and the content formats students need. This textbook has three main focuses aligned with the ScaPro-PjBL phases. The first phase emphasizes factual knowledge of TPaCK, with conceptual scaffolding to help pre-service teachers understand the relationships among content knowledge, pedagogical knowledge, and technological knowledge. The second phase provides conceptual knowledge about technology classifications in TPaCK and helps students design learning products. The third phase emphasizes procedural knowledge to enable students to operate TPaCK-supporting technologies appropriately. This flow allows the textbook to gradually move from basic understanding to practical application. The textbook also includes examples of products and activities relevant to the ScaPro-PjBL project, such as online lesson plans, digital student worksheets, technology-based formative evaluations, videos explaining concepts, online discussion forums, and tutorials on using learning applications. This content is crucial because pre-service teachers need more than just knowledge of TPaCK theory. They also need concrete examples and clear steps to turn theory into classroom-ready learning products. Thus, the textbook serves as scaffolding, helping students understand, design, and operate learning more systematically.

This study aims to develop a TPaCK textbook to support ScaPro-PjBL implementation, assess its validity and practicality through limited and extensive testing, and produce teaching materials suitable in TPaCK training for pre-service physics teachers. Scientifically, this study contributes a teaching materials development model aligned with the ScaPro-PjBL flow, scaffolding-based textbook content specifications, and strengthened TPaCK learning in physics teacher education and distance learning. The results of this study can strengthen the urgency and applicative value of similar teaching materials development in the future.

RESEARCH METHOD

This research is part of the development phase of an innovative model based on project-based learning (PjBL), which requires structured scaffolding to train TPaCK in pre-service physics teachers. The specific context of TPaCK is physics instruction in a distance learning environment. The development of this TPaCK textbook followed the preliminary research, development, prototyping, and assessment phases (Plomp, 2013). This article reports the preliminary results of all these stages through the extensive testing phase. Each phase specifies the content, validity, and practicality of the TPaCK textbook. In training TPaCK, the ScaPro-PjBL model requires students to complete projects in the form of TPaCK products, including online lesson plans, digital student worksheets, explanatory videos, and application-based formative evaluations. The TPaCK content specifications represent the general design of the textbook, based on the results of preliminary research that inform its validity and practicality evaluation. The developed textbook consists of five chapters: 1) TPaCK in Physics Learning: An Illustration, 2) TPaCK Framework, 3) TPaCK in the Context of Physics Distance Learning, 4) Emerging Technologies that Support TPaCK, and 5) TPaCK Products that Support Distance Learning.

The validity evaluation of the TPaCK textbook involved three physics education experts through a review/screening, in accordance with the statements of Nieveen & Folmer (2013) and Ramezani & Mostafavi (2025) on the evaluation of learning interventions. The validity evaluation instrument aligns with the textbook eligibility criteria set by the Indonesian National Agency of Education Standards (NAES), which include four main components: content, presentation, language, and graphical appropriateness. Validators assign assessments on a scale from 1 (least valid) to 10 (most valid). Validity is determined based on the average assessment score, with justification for the results in the following categories: 1) $7.75 \le P \le 10$, very valid; 2) $5.50 \le P = 7.75$, valid; 3) $3.25 \le P = 5.50$, moderate; $1.00 \le P \le 3.25$, less valid. The reliability value is calculated using the intraclass correlation coefficient equation for the two-way mixed effects model, the definition of absolute agreement, and the type of multiple raters (Hove et al., 2022; Koo & Li, 2016). The ICC(3,k) reliability criteria are 0.9–1 (excellent reliability), 0.75–0.9 (good reliability), 0.5–0.75 (moderate reliability), and 0–0.5 (poor reliability) (Koo & Li, 2016). The reliability value is also strengthened by Cronbach's Alpha, a measure of internal consistency for the textbook validation instrument used (Fraenkel et al., 2012). The Cronbach's Alpha reliability criteria are 0.9–1 (excellent reliability); 0.70–0.9 (high reliability); 0.5–0.70 (moderate reliability); and 0–0.5 (low reliability) (Hinton et al., 2014).

The practicality of the TPaCK textbook was assessed through limited and extensive trials using a practicality assessment questionnaire. This phase involved 21 students in the limited trial and 98 students in the extensive trial, each from physics education study programs at two campuses in East Java Province, Indonesia. Students assigned scores from 1–4 on the practicality questionnaire. Practicality results were determined based on the average assessment score, with justification in the following categories: 1) $3.25 \le P \le 4.00$, very practical; 2) $2.50 \le P < 3.25$, practical; 3) $1.75 \le P < 2.50$, less practical; $1.00 \le P < 1.75$, not practical. The reliability of the practicality assessment results is determined, as with validity evaluations, using ICC(3,k) and Cronbach's Alpha.

RESULTS AND DISCUSSION
Results

Table 1. Textbook content specifications as scaffolding in the ScaPro-PjBL model phase

ScaPro-PjBL Phase	Stages of TPaCK	Scaffolding Type	Textbook Content
Starting with essential questions	Factual knowledge about TPaCK in a teacher's practice.	Conceptual (Christodoulou & Angeli, 2022; Nickl et al., 2024)	• A teacher's stages in implementing TPaCK start with exploring content (CK), then designing learning strategies (PK), and finally integrating relevant technology (Bentri & Hidayati, 2022; Davis et al., 2014; Maisaroh et al., 2020; Siemsen & Jansen, 2014).
Designing a project with a timeline and checkpoints	Conceptual knowledge about technology classifications in TPaCK.	Conceptual (Atman Uslu & Gündüz, 2025; Liu et al., 2025)	• The TPaCK framework structure and specifications in distance learning cover the development of PCK to TPaCK in specific contexts (Atman Uslu & Usluel, 2019; Shiu, 2025). • Products that represent TPaCK include online lesson plans, digital student worksheets, formative evaluations, explanatory videos, and TPaCK performance demonstration plans. These plans take the form of online learning practices and the management of online discussion forums (Atman Uslu & Usluel, 2019; Shiu, 2025; Tondeur et al., 2020).
Providing tutorials on subject-specific techniques and methods	Procedural knowledge about how to operate features of supporting TPaCK technologies.	Procedural (Chernikova et al., 2020; Mansfield, 2022; Midun et al., 2020)	• Emerging technologies that support TPaCK in distance learning include: a) video shooting and editing techniques and applications, b) physics simulation applications, digital student worksheets, formative evaluations, and online discussion forums, and c) learning management systems (Al-Abdullatif, 2019; Falloon, 2020; Mouza, 2016; Voogt & McKenney, 2017).

Based on the results of preliminary research, specifically the literature review and the formulation of a conceptual and theoretical framework, the TPaCK textbook content specifications were obtained to support the ScaPro-PjBL model. The textbook was developed as scaffolding for students (pre-service physics teachers) to complete TPaCK projects during learning using the ScaPro-PjBL model. The textbook content specifications were compiled based on the alignment between the ScaPro-PjBL model phases, TPaCK mastery stages, scaffolding types, and content formats required by pre-service physics teachers, as presented in Table 1. Based on these specifications, the textbook contains theoretical material on TPaCK and provides steps for pre-service teachers to integrate knowledge of physics content, pedagogy, and technology in the context of distance learning.

In the first phase, starting with essential questions, the textbook content focuses on strengthening factual knowledge about TPaCK in teacher practice. At this stage, implementing TPaCK begins with exploring Content Knowledge (CK), continues with designing learning strategies through Pedagogical Knowledge (PK), and concludes with integrating technology relevant to the learning objectives. In the second phase, namely designing a project with a timeline and checkpoints, the textbook content focuses on strengthening conceptual knowledge of technology classification within the TPaCK framework. The textbook also includes examples of learning products that represent the application of TPaCK. In the third phase, namely providing tutorials on subject-specific techniques and methods, the textbook content focuses on strengthening procedural knowledge for operating TPaCK-supporting technology features. The textbook includes tutorials on technology use relevant to physics learning.

Table 2. The role of textbooks for supporting student activities in the ScaPro-PjBL phase

Phase	Main Student Activities	The Role of Textbooks
Starting with essential questions	• Memorize the components of knowledge required for teaching (TPaCK). • Listen to lecturers' explanations to understand the TPaCK conceptual framework for physics content in distance learning.	• mediators in learning, in this case between essential questions and their answers (Schuh et al., 2018) • sources of TPaCK content (Schuh et al., 2018; Segal, 2026)
Designing a project with a timeline and checkpoints	• Identify products to develop for the four TPaCK indicators in distance learning. • Identify the material, knowledge, and technical skill requirements for developing the project. • Design products, such as online lesson plans, digital student worksheets, formative evaluations, and explanatory videos, and plan online learning practices and discussion forums.	• project planning guides, including material requirements, knowledge, and technical skills (Warren, 2016) • assist with product identification and project output design (Grossman et al., 2021) • support decision-making in project design (Grossman et al., 2021)
Providing tutorials on subject-specific techniques and methods	• Listen to lecturers' guidance on the technical requirements for each project component. • Watch video tutorials on various software and applications to support TPaCK products and performance.	• guides for practice and development of technological knowledge (TK) (Maisarah et al., 2026; Musakhonovna, 2022) • provide live demonstrations of technology use (video-based tutorials) (Dennis et al., 2016; Saputra et al., 2026) • support tutorials through text, images, and video (Mayer, 2024)

The textbook is designed to support student activities during learning using the ScaPro-PjBL model. Table 2 shows the role of the TPaCK textbook in the three phases of the ScaPro-PjBL model. In the first phase, namely starting with essential questions, pre-service teachers focus on introducing and developing an initial understanding of the knowledge components required for teaching practice. The textbook mediates between essential questions and the answers pre-service teachers need and serves as a source of TPaCK content. In the second phase, in which a project is designed with a timeline and checkpoints, pre-service teachers shift from conceptual understanding to planning learning products. At this stage, they identify products to develop based on TPaCK indicators for distance learning, while the textbook serves as a project planning guide that supports product identification, project output design, and decision-making. In the third phase, which provides tutorials on subject-specific techniques and methods, pre-service teachers focus on mastering technical skills. They listen to lecturers' instructions about the technical requirements for each project component and watch video tutorials on software or applications that support the product and TPaCK performance. At this stage, the textbook serves as a practical guide and provides demonstrations of technology use through text, images, videos, and other visual media.

The textbook contains lecture materials used by lecturers and students to support the learning process. Table 3 summarizes the textbook validity analysis results for the ScaPro-PjBL model. The data in the table show that the validity scores for each aspect range from 8.40 to 9.00, indicating that they fall within the very valid (SV) category. The overall validity score averages 8.61, while the average ICC (3,k) is 0.860 and the average Cronbach's Alpha is 0.872, both of which are in the good range. The validator's suggestions have been followed up with the following improvements: (1) improving the depth and accuracy of the material in the form of examples/illustrations, (2) improving the consistency of terms, sentence structure, and simplification of technical terms, (3) improving the consistency and flow between chapters, and (4) adding advance organizers, summaries, practice questions, and other instruments that help student understanding.

Table 3. Validity of TPaCK textbooks for the ScaPro-PjBL model

Dimension	Validity Aspects	P	K	ICC (3,k)	K	α	K
content	content relevancy	8.40	SV	0.857	good	0.865	good
	language	8.42	SV				
	presentation techniques	8.44	SV				
graphic	book size	9.00	SV	0.863	good	0.879	good
	cover design	8.77	SV				
	content design	8.63	SV				
	Average	**8.61**	**SV**	**0.860**	**good**	**0.872**	**good**

Note: ICC (3,k) = *Intraclass Correlation Coeficient* (*Two-Way Mixed Effects, Mean of k Raters*); α = *Cronbach's Alpha*; P = validity score; K = category; SV = very valid

In detail, the material validity aspects, namely content, language, and presentation techniques, scored 8.40, 8.42, and 8.44, respectively. The graphic aspects, namely book size, cover design, and content design, scored 9.00, 8.77, and 8.63, respectively. All aspects demonstrated a high and consistent level of validity, meeting the validity achievement criteria (validity score ≥ 5.50), with absolute agreement (ICC > 0.75) and good internal consistency (Cronbach's Alpha > 0.70). This confirms that the validated textbook meets the criteria of clear material structure, communicative language, effective material presentation, and graphic design that supports the learning process using the ScaPro-PjBL model to train TPaCK.

Table 4. Practicality of the TPaCK textbook in limited and extensive trials

No	Dimension	Average Score / Criteria	Limited Trial Class	Extensive Trial Class			
				A	B	C	D
1	Ease of use	P	2.71	3.33	3.33	3.31	3.41
		Category	practical	SP	SP	SP	SP
		α - ICC	0.853	0.917	0.907	0.870	0.909
		Category	good	excellent	excellent	good	excellent
2	Material usefulness	P	2.70	3.38	3.26	3.36	3.29
		Category	practical	SP	SP	SP	SP
		α - ICC	0.866	0.892	0.842	0.906	0.904
		Category	good	good	good	excellent	excellent
3	Learning connection	P	2.71	3.52	3.30	3.30	3.35
		Category	practical	SP	SP	SP	SP
		α - ICC	0.893	0.941	0.786	0.918	0.851
		Category	good	excellent	good	excellent	good
4	Time and flexibility	P	2.64	3.31	3.29	3.38	3.26
		Category	practical	SP	SP	SP	SP
		α - ICC	0.778	0.866	0.890	0.826	0.851
		Category	good	good	good	good	good

Note: "α - ICC" = α for limited trial - ICC for extensive trial; ICC = *Intraclass Correlation Coefficients*; P = average practicality score; SP = very practical

Details on the practicality scores of the TPaCK textbook and its reliability are shown in Table 4. The results of limited and extensive trials indicate that the textbook is practical to very practical for student use. The practicality score is assessed across four dimensions: ease of use, material benefits, relevance to learning, and time and flexibility. For ease of use, the textbook obtained an average score of 2.71 in the limited trial and 3.33–3.41 in the extensive test, with a very practical (SP) category and high reliability (α = 0.909–0.917). For material benefits, the limited trial yielded an average score of 2.70, while the extensive test showed scores of 3.26–3.38, with a reliability of α = 0.842–0.906. Relevance to learning also showed positive results, with a limited test score of 2.71, a broad test score of 3.30–3.52, and a reliability of α = 0.786–0.941. For time and flexibility, the limited test score was 2.64, and the broad test was 3.26–3.38, both falling within the SP category, with reliabilities of α = 0.826–0.890.

Discussion

The TPaCK textbook was developed as a learning tool to support the implementation of the ScaPro-PjBL model, which consists of six phases: starting with essential questions, designing a project with a timeline and checkpoints, providing tutorials on subject-specific techniques and methods, monitoring project progress, assessing and publishing the product, and reflecting on the work experience. Accordingly, this implementation focuses on three initial phases that are crucial for developing pre-service teacher competencies: starting with essential questions, designing a project with a timeline and checkpoints, and providing tutorials on subject-specific techniques and methods.

The validation results for the student textbook, presented in Table 3, indicate that the TPaCK textbook is highly valid across the material and graphic dimensions. These results show that the textbook functions as a supporting component for pedagogical values and the curriculum system in the learning process (Fey & Matthes, 2018). As Reid & Maybee (2022) stated, textbooks or other teaching materials should be evaluated primarily against learning objectives and learning activities. Student response data on textbook practicality from the limited and extensive trials in Table 4 indicate that students found the textbook easy to use, the material useful and relevant to the ScaPro-PjBL learning flow, and flexible within the allocated learning time. The developed TPaCK textbook serves as a reference for students' TPaCK training, with features specifically designed to align with the ScaPro-PjBL model flow. This alignment strengthens the textbook's role in guiding class discussions, framing issues and case examples, providing process illustrations, identifying critical questions, and enriching the learning experience (Reid & Maybee, 2022).

Evidence of the practicality of the ScaPro-PjBL model is provided by the student textbook as teaching material for students' TPaCK-PDL training. Student responses indicate a highly practical category for textbooks, as presented in Table 4. This shows that the textbooks support the implementation of the ScaPro-PjBL model through ease of use, material benefits, relevance to learning, and time and flexibility of use. This aligns with textbook characteristics, which require the use of books and other resources to provide students with adequate knowledge and preparation to achieve successful project outcomes (Tain et al., 2023). In practice, textbooks are presented as web-based media on the Google Sites platform. Electronic textbooks offer flexibility (Sucilestari et al., 2025), convenience, and accessibility, and help students confirm information during PjBL implementation (Wang, 2020). The role and function of textbooks in PjBL are reinforced by previous research, which found that the use of e-books significantly improves student learning outcomes, independent learning skills, and creativity (Ratnawati et al., 2023), enriching the learning experience and encouraging the development of digital literacy skills (Sucilestari et al., 2025).

Students assessed the textbook as providing useful and relevant material for implementing the ScaPro-PjBL model in practicing TPaCK, as shown in the practicality assessment results in Table 4 for the material benefits dimension. This confirms that the textbook's material aligns with student needs and the curriculum's scope. The development of textbook material must consider the scope of the material and curriculum standards to ensure its relevance to student needs (Krajcik et al., 2008). This aligns with Revelle et al. (2020), who recommended that when developing textbooks for PjBL, the material must be authentic and link the project's objectives and products to real-world issues or student needs. The relevance of the textbook material to student needs has also been demonstrated by Edelson et al. (2021) and He et al. (2023).

Students considered the flexibility of use and time allocation highly practical, as shown in Table 4. This indicates that the textbook supports learning within the available time while remaining flexible in use. The textbook is presented to students via a web-based platform (Google Sites). As Jung et al. (2001) stated, this addresses time and space constraints, enables synchronous or asynchronous access, and provides flexibility in allocating time for student interaction. Google Sites, as an e-learning platform, can be used freely to design teaching materials and learning activities Baziukė et al. (2025).

With this flexibility in time and the use of textbooks, students can optimize their learning outcomes in the context of collaborative PjBL (ChanLin, 2012).

In the Starting with Essential Questions phase, the validity of the TPaCK textbook is evident in its relevance to pre-service teachers' initial needs for understanding the basic integration of content knowledge, pedagogy, and technology. Content in this phase should focus on factual knowledge of TPaCK in teacher practice, because pre-service teachers are not yet directed to choose technology directly, but rather to first understand the material's characteristics and learning needs. This principle aligns with the criteria for textbook validity that emphasize the suitability of the content to learning objectives, the accuracy of the substance, a systematic material structure, and suitability to the user level (Devetak & Vogrinc, 2013; Fey & Matthes, 2018). In the context of TPaCK, a valid textbook needs to explain that learning begins with the exploration of Content Knowledge (CK), continues with strategy design through Pedagogical Knowledge (PK), and then concludes with the integration of relevant technology through Technological Knowledge (TK) (Bentri & Hidayati, 2022; Davis et al., 2014; Maisarah et al., 2026). This sequence is crucial to ensure that technology is not positioned as an end in itself, but as a tool that supports learning outcomes. Therefore, the appropriate type of scaffolding in this phase is conceptual scaffolding. Conceptual support helps pre-service teachers understand the relationship between CK, PK, and TK, fill initial knowledge gaps, and build a foundation for thinking before moving on to more complex instructional design stages (Christodoulou & Angeli, 2022; Nickl et al., 2024). The integrated presentation of support also strengthens the validity of textbooks, as pre-service teachers can develop more logical design justifications when content, pedagogical, and technological information are not presented separately (Janssen et al., 2019; Rasamimanana et al., 2026). Therefore, a TPaCK textbook in the "Starting with Essential Questions" phase can be declared valid if its content specifications emphasize factual TPaCK knowledge, rationally follow the stages of CK, PK, and TK, and use conceptual scaffolding to systematically build pre-service teachers' initial understanding.

In the Starting with Essential Questions phase, the practicality of the TPaCK textbook is clear in its ability to support students' activities in understanding the initial concepts of TPaCK. The textbook functions as a mediator connecting essential questions with conceptual answers, allowing students to link learning questions to relevant material (Schuh et al., 2018; Segal, 2026). Practicality is also demonstrated through the provision of structured TPaCK content covering CK, PK, and TK, along with examples of their application in technology-based physics teaching. The clear flow of material, user-friendly navigation, and ease of access improve the student learning experience without causing confusion (Tucker & Charette, 2025; Wan Sulaiman & Mustafa, 2020). Furthermore, textbooks provide conceptual, procedural, and instructional scaffolding that enables students to remember, listen to lecturers' explanations, and understand the TPaCK framework within their proximal zone (J. He & Lv, 2025; Mesa & Griffiths, 2012; Wass & Golding, 2014; Xia et al., 2026). The textbook's practicality is further strengthened by its function as a self-study resource and activity guide, enabling students to develop their understanding of TPaCK independently while simultaneously laying the foundation for more complex learning applications (Gautschi, 2018; Ibragimov et al., 2016; Ivanova & Osmolovskaya, 2016). Thus, TPaCK textbooks at this stage are practical because they support student activities in an integrated, clear, accessible manner and provide appropriate scaffolding for building initial understanding.

In the Designing a Project with a Timeline and Checkpoints phase, the validity of a TPaCK textbook is determined by its ability to provide conceptual content that supports project design, workflow organization, and checkpoint establishment. A valid textbook emphasizes the classification of technologies within the TPaCK framework, which includes examples of applicable learning products, such as online learning implementation plans, digital worksheets, technology-based formative evaluations, concept videos, and TPaCK performance demonstrations (Atman Uslu & Gündüz, 2025; Shiu, 2025; Tondeur et al., 2020). The conceptual scaffolding presented is applicable because it helps teachers understand relevant technologies and use online discussion forums to monitor projects and encourage student collaboration. Furthermore, textbook content must be accurate, relevant to the learning objectives, appropriate to the student's level, and logically and systematically organized (Devetak & Vogrinc, 2013; Fey & Matthes, 2018; Nawani, 2010). The systematic structure and design of the textbook, integrating text, illustrations, tables, and learning apparatus, further strengthen validity by making it easier for students to understand the material. This also supports following the project flow and checkpoints (Ibragimov et al., 2016; Kodliuk et al., 2021; Numanoglu & Bayir, 2009). Therefore, a TPaCK textbook is considered valid at this stage if it facilitates conceptual understanding, provides concrete product guidance, and serves as a mediator that systematically connects project questions with TPaCK implementation practices.

In the "Designing a Project with a Timeline and Checkpoints" phase, the practicality of a TPaCK textbook is evident in its role in helping students move from conceptual understanding to planning learning products. The textbook serves as a project planning guide, helping students identify the needs of physics materials, pedagogical knowledge, digital media, technical skills, and the form of outputs to be developed (Devetak & Vogrinc, 2013; Ibragimov et al., 2016; Warren, 2016). This role is crucial because students need to determine products that align with TPaCK indicators in distance learning, such as online lesson plans, digital worksheets, formative evaluations, explanatory videos, online learning practices, and online discussion forum management (Gautschi, 2018; Grossman et al., 2021; Lee et al., 2023). The practicality of textbooks is also evident in their ability to support decision-making during the design process. Students not only select products but also rationally define materials, learning strategies, relevant technology, timelines, and project checkpoints (Atman Uslu & Gündüz, 2025; Grossman et al., 2021; Mesa & Griffiths, 2012). This support is reinforced through conceptual scaffolding that helps students connect content, pedagogy, and technology into concrete learning designs (Kilic, 2018; Liu et al., 2025; Polly & Byker, 2020). To be practical, textbooks also need to have a clear content flow, easy navigation, flexible access, and activities that encourage students to interpret project requirements, represent ideas, develop designs, and revise designs based on learning objectives (Glasnovic Gracin, 2018; Sievert et al., 2021; Tucker & Charette, 2025; Wan Sulaiman & Mustafa, 2020). Thus, TPaCK textbooks at this stage can be considered practical because they function as project guides, product identification tools, design decision support, and learning mediators that facilitate students in designing TPaCK outputs independently and collaboratively.

In the Providing Tutorials on Subject-Specific Techniques and Methods phase, the validity of a TPaCK textbook is determined by its ability to provide procedural guidance that systematically supports technology mastery. Valid textbooks provide step-by-step tutorials for operating TPaCK's supporting technology features, including video recording and editing applications, physics simulation applications, digital worksheets, online formative assessments, online discussion forums, and learning management systems (Al-Abdullatif, 2019; Chernikova et al., 2020; Mansfield, 2022; Midun et al., 2020). The procedural scaffolding provided helps teachers follow a sequence of technology use, from selecting applications and operating key features to creating content and integrating it into physics learning projects (Devetak & Vogrinc, 2013; Kilic, 2018). The validity of a textbook is also supported by content accuracy, relevance to learning objectives, appropriateness to the student's ability level, and systematic and logical organization of steps (Fey & Matthes, 2018; Nawani, 2010). Optimal textbook structure and design, including text, illustrations, tables, and learning apparatus, support understanding of technical tutorials (Bezemer & Kress, 2010; Ibragimov et al., 2016; Kodliuk et al., 2021). Furthermore, clear, easy-to-understand language and informative illustrations enhance students' ability to follow procedures (Crossley et al., 2011; Fey & Matthes, 2018). Therefore, a TPaCK textbook in the technical tutorial phase is valid because it integrates procedural scaffolding, step-by-step guidance, relevant content, and adequate visual support.

In the Providing Tutorials on Subject-Specific Techniques and Methods phase, the practicality of the TPaCK textbook lies in its ability to help pre-service teachers master the technical skills of using learning technology. At this stage, students listen to lecturers' instructions on the technical requirements of each project component and watch tutorials on using software and applications that support the product and TPaCK's performance. Therefore, the textbook serves as a practical guide to developing technological knowledge through systematic, easy-to-follow steps for using technology (Huang & Lajoie, 2021; Maisarah et al., 2026; Musakhonovna, 2022). The guide clarifies the technical requirements for creating learning videos, using physics simulation applications, compiling digital worksheets, developing online formative evaluations, managing discussion forums, and utilizing learning management systems. The practicality of textbooks is also enhanced when lecturer instructions are supported by procedural scaffolding in the form of explicit instructions, examples of work steps, procedural breakdowns, and step-by-step exercises that help students reduce confusion in carrying out technical tasks (Chernikova et al., 2020; Lin & Hou, 2023; Mansfield, 2022; Midun et al., 2020). Furthermore, textbooks include demonstrations of technology use through video-based tutorials, as live demonstrations help students see the application process more concretely (Dennis et al., 2016; Saputra et al., 2026). Tutorials are also more practical when presented multimodally, combining text, images, screenshots, diagrams, and videos, so students can understand procedures through several complementary forms of representation (Lee et al., 2023; Mayer, 2024; Tucker & Charette, 2025). Thus, the TPaCK textbook at this stage is practical because it serves as a guide for TPaCK practice, provides technology demonstrations, offers multimodal tutorial resources, and provides procedural scaffolding relevant to TPaCK products in physics learning.

TPaCK products and mastery of digital skills can support the SDGs, especially SDG 4, by strengthening learning quality, educational access, and student preparedness for sustainability issues. More specifically, TPaCK serves as an integrative framework that connects material mastery, pedagogical strategies, and digital skills to foster learning that is inclusive, adaptive, and aligned with the sustainable development agenda. Teachers' digital competence is crucial because they need to select digital platforms, learning videos, online assessments, and technology-based pedagogical strategies that align with students' learning needs (Kangwa et al., 2026; Mat Salleh et al., 2025; Méndez et al., 2022). TPaCK products such as digital presentations, videos, simulations, digital worksheets, and activity-based learning designs also help teachers translate SDG issues into more measurable learning objectives, classroom activities, and assessments (Castaño et al., 2025; Gökbulut, 2026; Xiao et al., 2026). In addition, the use of LMS, e-content, captioned videos, online learning, and digital platforms can expand learning access for students in remote areas, vulnerable groups, people with disabilities, and students with different learning needs (Chen, 2023; Kangwa et al., 2026; Kulal et al., 2024; Matsieli & Mutula, 2024). The hybrid learning model also supports learning sustainability because the learning process can continue during pandemics, disasters, or limited face-to-face meetings through the use of Google Classroom, Telegram, Google Forms, videos, and online classes (Martins et al., 2025; Mat Salleh et al., 2025; Méndez et al., 2022). On the other hand, mastery of digital skills through AI, Web 2.0, CAD/CAM/CAE, simulation, and digital fabrication can train students to think critically, collaborate, innovate, and develop technology-based solutions to sustainability issues (Castaño et al., 2025; Gökbulut, 2026; Xiao et al., 2026).

Overall, the results of this study indicate that the TPaCK textbook meets the criteria for validity and practicality as a supporting teaching material for the ScaPro-PjBL model. This textbook is relevant to the three main phases targeted for development: Starting with Essential Questions, Designing a Project with a Timeline and Checkpoints, and Providing Tutorials on Subject-Specific Techniques and Methods. In terms of validity, the textbook's content aligns with the content specifications, TPaCK stages, and the types of scaffolding required for each phase. In terms of practicality, the textbook helps students understand TPaCK concepts, design learning products, determine project requirements, follow technology tutorials, and use materials flexibly. High reliability confirms consistent observer assessments, ensuring the textbook can be used confidently to support the implementation of the ScaPro-PjBL model.

CONCLUSION

Fundamental Finding: Based on expert evaluation and trials, the TPaCK textbook is valid and practical as supporting teaching material for the ScaPro-PjBL model in TPaCK training for pre-service physics teachers. **Implication:** The validity and practicality criteria in this textbook can serve as a clear framework for researchers developing similar teaching materials. These specifications can guide future studies to replicate or further develop the ScaPro-PjBL model. **Limitation:** This research was limited to pre-service physics teachers in a learning environment with a specific TPaCK context, namely distance learning. **Future Research:** Further research can develop the textbook for other content and contexts by adjusting the specifications and practicality criteria based on student responses and needs.

AUTHOR CONTRIBUTIONS

Gaguk Resbiantoro: Conceptualization, Methodology, Investigation, Data Curation, Formal Analysis, Software, Validation, Visualization, Writing – Original Draft, and Project Administration. **Wasis:** Conceptualization, Supervision, Methodology, Validation, Resources, Writing – Review & Editing, and Funding Acquisition. **Wahono Widodo:** Methodology, Validation, Formal Analysis, Supervision, Writing – Review & Editing, and Resources. All authors contributed to the study design, critically reviewed the manuscript, approved the final version for publication, and agreed to be accountable for all aspects of the work.

CONFLICT OF INTEREST STATEMENT

The authors declare that there are no financial, personal, professional, or institutional conflicts of interest that could have influenced the design, conduct, analysis, interpretation, or reporting of this study. The authors confirm that the research was carried out independently and that the findings and conclusions presented in this article are solely based on the evidence obtained during the research process.

ETHICAL COMPLIANCE STATEMENT

The authors affirm that this manuscript complies with accepted standards of research and publication ethics. The study was conducted with academic integrity, and the manuscript represents original work that has not been published or submitted elsewhere. All sources have been appropriately acknowledged, and the authors confirm that the manuscript is free from plagiarism, data fabrication, data falsification, and any other form of unethical research or publication practice.

STATEMENT ON THE USE OF AI OR DIGITAL TOOLS IN WRITING

Artificial intelligence (AI) tools were used only to support language editing and the preparation of graphical illustrations in this manuscript. Grammarly was employed to improve grammar, sentence clarity, and overall language readability, and ChatGPT (OpenAI) was used to assist in creating graphical illustrations based on conceptual frameworks developed by the authors. AI was not used to generate research ideas, collect or analyze data, interpret findings, develop theoretical arguments, or formulate the conclusions of this study. All AI-assisted outputs, including language revisions and graphical illustrations, were carefully reviewed, verified, and revised by the authors. The authors take full responsibility for the originality, accuracy, and integrity of the manuscript.

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