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Product Design Worksheets as Procedural Scaffolding in the ScaPro-PjBL Model for Strengthening Pre-Service Physics Teachers' TPaCK toward SDG 4

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ABSTRACT

Objective: *To evaluate the validity and practicality of worksheets as a form of procedural scaffolding within the ScaPro-PjBL model for training TPaCK.* ***Method:*** *The design of these worksheets followed Plomp's (2013) design research stages: preliminary research, development/prototyping, and assessment. Developed alongside the innovative Scaffolded Product in Project-Based Learning (ScaPro-PjBL) model, the worksheets underwent expert review for validity and were piloted with 21 students in a limited pilot and 98 students in a broad pilot from two East Java campuses in Indonesia. Validity scores, reliability statistics (ICC(3, k) and Cronbach's Alpha), and practicality results were collected throughout these stages.* ***Results:*** *The worksheets were found to be valid, with an average validity score of 8.65 (very valid), an ICC(3, k) of 0.819 (good reliability), and an a of 0.839 (good reliability). Practicality was also confirmed, with an average score of 3.26-3.50 (very practical) in extensive trials. High reliability in practicality assessment was recorded using both $ICC_{(3,k)}$ and Cronbach's Alpha.* ***Novelty:*** *The six worksheets in this study were specifically designed as scaffolding in project-based learning to support the development of the ScaPro-PjBL model. The specifications for worksheet development are detailed in this article. This study contributes to SDG 4 (Quality Education) by providing structured, student-centered learning resources that enhance project-based learning implementation, promote higher-order thinking, and support equitable, high-quality science education.*

INTRODUCTION

According to the P21 Framework, information, media, and technology skills are essential 21st-century competencies (Battelle for Kids, 2019; Kayhan & Korkmaz, 2024; Rodríguez-Loinaz et al., 2024). To meet these needs, the learning process must integrate ICT (Claro et al., 2024). Teachers must drive this ICT integration as facilitators (Lindín et al., 2023; Claro et al., 2024). Pre-service teachers are trained to use ICT in learning and adapt to 21st-century transformations (Brown et al., 2021; Van Katwijk et al., 2023). 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). The TPaCK framework represents their readiness for modern educational contexts (Mohebi, 2021; Carneiro et al., 2022) and is relevant for developing professional competences in pre-service physics teachers (Tondeur et al., 2021; Osorio Vanegas et al., 2025). Thus, TPaCK was selected to assess pre-service teachers' abilities to integrate ICT.

The development of technology-integrated learning is closely aligned with the Sustainable Development Goals (SDGs), particularly SDG 4 (Quality Education), which emphasizes inclusive, equitable, and high-quality education while promoting lifelong learning opportunities for all. Achieving this goal requires prospective teachers to