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ORIGINAL

# Developing the TCK-PPDL Model: An Integrated Learning Approach to Promote Critical Thinking in Primary Science Education

## Desarrollando el Modelo TCK-PPDL: Un Enfoque de Aprendizaje Integrado para Promover el Pensamiento Crítico en la Educación Primaria de Ciencias

Umar Darwis[1], Sumarno[1], Sriadhi[1]

[1]Universitas Negeri Medan. Medan, Indonesia.

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**Corresponding Author:** Umar Darwis

## ABSTRACT

**Introduction:** this study addresses the urgent need for pedagogical innovation in Indonesian elementary science education by developing the TCK-PPDL (Think Compu Kids-Problem, Project, Discovery Learning) model. The model is designed to improve students' Higher-Order Thinking Skills (HOTS) and integrate Computational Thinking (CT), in response to persistent underperformance in international assessments such as PISA and the demands of the Merdeka Curriculum.
**Method:** using the Plomp development research model, the study was conducted in three phases: (1) preliminary investigation through needs analysis and curriculum review; (2) design and prototyping of the TCK-PPDL model along with its supporting instruments (teacher guidebook and student module); and (3) field testing in two elementary schools in Medan, Indonesia. Data were collected through expert validation instruments, practicality surveys for teachers and students, and pretest-posttest assessments.
**Results:** the model demonstrated high content validity (Aiken's V = 0,85), very practical implementation as rated by teachers (87,50 %) and students (88,20 %), and moderate effectiveness with N-Gain scores ranging from 0,31 to 0,43. Significant correlations between pretest and posttest scores (r = 0,892-0,973) confirmed measurable improvements in students' HOTS.
**Conclusions:** the TCK-PPDL model is a promising integrative approach that blends constructivist learning, computational thinking, and higher-order thinking skills. It is practical for classroom implementation and holds potential for improving student learning outcomes and supporting curriculum reform in Indonesian elementary education.

**Keywords**: TCK-PPDL Model; Higher-Order Thinking Skills; Computational Thinking; Elementary Education; Instructional Development.

## RESUMEN

**Introducción:** este estudio responde a la urgente necesidad de innovación pedagógica en la educación científica primaria de Indonesia mediante el desarrollo del modelo TCK-PPDL (Think Compu Kids-Aprendizaje Basado en Problemas, Proyectos y Descubrimiento). El modelo está diseñado para mejorar las Habilidades de Pensamiento de Orden Superior (HOTS) e integrar el Pensamiento Computacional (CT), en respuesta al bajo rendimiento en evaluaciones internacionales como PISA y las demandas del Currículo Merdeka.
**Método:** utilizando el modelo de investigación de desarrollo de Plomp, el estudio se llevó a cabo en tres fases: (1) investigación preliminar mediante análisis de necesidades y revisión curricular; (2) diseño y creación de prototipos del modelo TCK-PPDL junto con sus instrumentos de apoyo (guía para docentes y módulo estudiantil); y (3) prueba de campo en dos escuelas primarias en Medan, Indonesia. Los datos se recopilaron mediante instrumentos de validación de expertos, encuestas de practicidad para docentes y estudiantes, y evaluaciones pretest-postest.

**Resultados:** el modelo demostró una alta validez de contenido (V de Aiken = 0,85), una implementación muy práctica según la valoración de los docentes (87,50 %) y los estudiantes (88,20 %), y una efectividad moderada con puntajes de N-Gain que oscilaron entre 0,31 y 0,43. Las correlaciones significativas entre los puntajes del pretest y postest (r = 0,892–0,973) confirmaron mejoras medibles en las HOTS de los estudiantes.
**Conclusiones:** el modelo TCK-PPDL es un enfoque integrador prometedor que combina el aprendizaje constructivista, el pensamiento computacional y las habilidades de pensamiento de orden superior. Es práctico para su implementación en el aula y tiene potencial para mejorar los resultados de aprendizaje estudiantil y apoyar la reforma curricular en la educación primaria de Indonesia.

**Palabras clave:** Modelo TCK-PPDL; Habilidades de Pensamiento de Orden Superior; Pensamiento Computacional; Educación Primaria; Desarrollo Instruccional.

## INTRODUCTION

Education plays a critical role in shaping individuals and societies, with its functions extending beyond the transmission of knowledge to include character building, critical thinking development, and societal empowerment.[1,2] In Indonesia, the importance of education is legally embedded in the National Education System Law No. 20 of 2003, which emphasizes the development of learners' potential to become faithful, knowledgeable, and responsible citizens.[3]

Despite substantial efforts to improve educational quality, the Indonesian education system continues to face significant challenges, especially in the aftermath of the COVID-19 pandemic. The crisis has exacerbated learning loss, further widening educational gaps. In response, the Ministry of Education, Culture, Research, and Technology introduced the Merdeka Curriculum as part of the Merdeka Belajar initiative to address these concerns. This curriculum emphasizes essential competencies, holistic understanding, and flexibility in learning approaches.[4]

A notable feature of the Merdeka Curriculum at the elementary level is the integration of Computational Thinking (CT) within subjects such as Bahasa Indonesia, Mathematics, and IPAS (Science and Social Studies). CT is increasingly recognized as a critical 21st-century skill, involving not only technical competencies but also logical, analytical, and creative problem-solving abilities.[5,6] However, recent data from the Programme for International Student Assessment (PISA) 2022 reveal that Indonesian students rank poorly in mathematics, science, and reading, with mean scores far below the OECD average.[7] These findings reflect an ongoing deficiency in higher-order thinking skills (HOTS), particularly in areas such as critical analysis, problem-solving, and innovation.

Comparable challenges have been observed globally. Research in countries such as China, Malaysia, Thailand, and Kazakhstan indicates the importance of fostering HOTS and the need for innovative pedagogical approaches to do so.[8,9,10,11] Moreover, computational thinking has been increasingly embraced in the Nordic countries and regions like Hong Kong, where it is integrated into core curricula and creative domains to foster early cognitive development.[12,13]

In Indonesia, both HOTS and CT skills among elementary school students remain underdeveloped. For example, Rahayu et al. found that many students struggle with algorithmic thinking and pattern recognition—core components of computational thinking. These deficiencies suggest the need for strategic educational innovation to embed CT in teaching practices more effectively.

Numerous studies have affirmed the synergistic relationship between computational thinking and critical thinking, as well as their combined influence on students' academic and cognitive performance.[14,15,16] To bridge these gaps, it is essential to develop and validate pedagogical models that holistically integrate computational thinking into the elementary curriculum—particularly within IPAS subjects, which combine interdisciplinary content and real-world applications.

This study responds to this urgent educational need by developing and validating the Think Compu Kids-Problem, Project, Discovery Learning (TCK-PPDL) model. This integrative model combines the strengths of Problem-Based Learning (PBL), Project-Based Learning (PjBL), and Discovery Learning to foster both HOTS and computational thinking in elementary school students. The study also includes the development of a practical teaching manual to assist educators in the effective implementation of the model.

Ultimately, this research aims to contribute to the transformation of learning experiences in Indonesian elementary schools, better preparing students for the demands of a digitally driven future while supporting national curriculum goals and global educational standards.

## METHOD

### Ethics and Parental Permission

This research was conducted in accordance with ethical standards for studies involving human participants, particularly minors. Prior to data collection, ethical approval was obtained from the institutional ethics committee of Universitas Negeri Medan. All participating schools granted formal consent, and the school principals approved the research activities to be carried out within their institutions.

Given that the participants were elementary school students, written informed consent was obtained from the parents or legal guardians of each child involved in the study. The consent form included information about the purpose of the research, the procedures involved, potential benefits and risks, confidentiality measures, and the voluntary nature of participation. Students were also given age-appropriate explanations and were assured that they could withdraw from the study at any time without any academic consequences.

Confidentiality of all personal data was strictly maintained. Student identities were anonymized using coded identifiers, and all data were stored securely and used solely for research purposes.

### Research Design

This study employed a developmental research design using the Plomp model,[17] which consists of three phases: (1) Preliminary Investigation, (2) Design and Prototyping, and (3) Field Testing and Evaluation. The goal was to develop and validate a learning model named TCK–PPDL (Think Compu Kids–Problem, Project, Discovery Learning) to enhance students' Higher-Order Thinking Skills (HOTS) in elementary science (IPAS) instruction.

### Development Procedure

*Preliminary Investigation*

This phase involved needs analysis conducted through:

- Pre-test to assess students' existing HOTS levels.
- Classroom observations to understand student characteristics.
- Teacher interviews to identify instructional challenges.
- Curriculum analysis to ensure model alignment with the *Merdeka Curriculum*.

*Design and Prototyping*

Based on the analysis, the learning model was designed by synthesizing theoretical frameworks of PBL, PjBL, Discovery Learning, and Computational Thinking. A draft model named TCK–PPDL was developed, accompanied by:

- A teacher guidebook for classroom implementation.
- A student module containing HOTS-oriented learning activities.

Expert validation was conducted involving:

- Two university lecturers (PhD in Education).
- One experienced elementary school teacher.

Feedback was collected using a Likert-scale questionnaire to assess the model's design, cognitive support, student engagement, adaptability, and cultural relevance. Supporting materials (guidebook and module) were also validated for content, language, structure, and layout by content experts, language experts, and instructional designers.

*Field Testing and Evaluation*

After validation, a small-group trial was conducted in two public elementary schools in Medan:

- UPT SD Negeri 060817 (n = 22)
- UPT SD Negeri 060924 (n = 19)

This stage included formative and summative evaluations to identify model effectiveness and areas for revision.

### Participants

Participants were Grade V students and teachers from two public elementary schools in Medan. The research took place in February 2025, during the 2024/2025 academic year.

### Instruments and Data Collection

Several instruments were developed to collect quantitative and qualitative data:

**Model Validation Instruments**

- Expert validation questionnaires assessed the model based on seven categories: design structure, student activity, adaptability, cognitive strategy, reflective learning, sociocultural integration, and practical application.[18,19]
- Language and content validation checklists for the guidebook and module followed standard criteria of relevance, clarity, consistency, and accessibility.[20,21]

**Practicality Instruments**

- Teacher and student questionnaires using Likert-scale responses measured engagement, instructional clarity, adaptability, relevance, and satisfaction.[22]

**Effectiveness Instruments**

- A pre-test and post-test to evaluate students' HOTS based on Bloom's taxonomy levels (C4–C6), with open-ended questions in IPAS topics: natural disasters, environmental issues, and sustainability.

**Data Analysis**

*Validity Analysis*

Expert ratings were analyzed using Aiken's V to determine content validity, with interpretation criteria:

- 0,80–1,00 = Very Valid.
- 0,60-0,79 = Valid.
- 0,40–0,59 = Fairly Valid.
- <0,40 = Not Valid.

*Effectiveness Analysis*

Effectiveness was measured using the N-Gain formula:

$$G = \frac{Posttest - Pretest}{Maximum\ Score - Pretest}$$

With interpretation:

- $g > 0,7$ = High.
- $0,3 \leq g \leq 0,7$ = Moderate.
- $g < 0,3$ = Low.

## RESULTS

**Developed TCK-PPDL Learning Model**

The Think Compu Kids-Problem, Project, Discovery Learning (TCK-PPDL) model was developed through a structured process that incorporates elements of Problem-Based Learning (PBL), Project-Based Learning (PjBL), Discovery Learning, and Computational Thinking. The model includes six main stages: (1) Concrete Context, (2) Collaboration and Exploration, (3) Modeling and Representation, (4) Generalization and Abstraction, (5) Systematic Solution and Application, and (6) Reflection and Feedback. Each stage is aligned with higher-order thinking skills (HOTS), such as analysis, evaluation, abstraction, algorithmic thinking, and metacognitive reflection.

**Validity of the TCK-PPDL Model**

Validation was conducted by three experts (two university lecturers and one primary school teacher). The average Aiken's V coefficient was 0,85, indicating a very valid model. Table below summarizes the results:

**Table 1.** Expert validation of TCK-PPDL learning model

| Evaluation Indicator | Aiken's V | Interpretation |
|---|---|---|
| Instructional Design | 0,83 | Very Valid |
| Student Activity | 0,84 | Very Valid |
| Adaptability and Personalization | 0,69 | Valid |
| Cognitive and Metacognitive Strategies | 0,88 | Very Valid |
| Reflective and Experiential Learning | 0,94 | Very Valid |
| Sociocultural Relevance | 0,78 | Valid |
| Practical Application | 0,91 | Very Valid |

The high validity scores across components suggest that the model design is pedagogically sound, adaptable to diverse learning needs, and effectively integrates reflective and experiential learning principles.

**Practicality of the TCK-PPDL Model**

*Teachers' Response*

The practicality test among teachers resulted in a mean score of 87,50 %, categorized as very practical. This indicates that the model supports effective content delivery, adaptation to classroom conditions, and promotes active learning.

**Table 2.** Practicality Test For Teachers

| Indicator | Score (%) | Interpretation |
|---|---|---|
| Content Delivery and Effectiveness | 85,00 | Very Practical |
| Adaptation and Flexibility | 85,00 | Very Practical |
| Resource Support | 87,50 | Very Practical |
| Student Participation and Outcomes | 92,50 | Very Practical |

*Students' Response*

Student feedback also indicated high practicality, with an average score of 88,20 %. Students reported high engagement, clear instructions, relevance to real life, increased confidence, and satisfaction with the learning process.

**Table 3. Practicality Test For Students**

| No. | Evaluation Indicator | Score (%) | Interpretation |
|---|---|---|---|
| 1 | Interest and Participation | 88,00 | Very Practical |
| 2 | Instruction Clarity and Comprehension | 83,00 | Very Practical |
| 3 | Relevance and Real-Life Application | 93,00 | Very Practical |
| 4 | Feedback and Confidence | 88,00 | Very Practical |
| 5 | Attitude and Learning Satisfaction | 89,00 | Very Practical |
| | Average | 88,20 | Very Practical |

*Effectiveness of the TCK-PPDL Model*

The model was tested in two elementary schools. Paired *t-tests* and N-Gain scores were used to assess effectiveness.

*Results from SD Negeri 060817*

**Table 4.** Pretest and posttest results of elementary school students 060817

| Test Pair | Pre-Test Mean | Post-Test Mean | Gain | Interpretation |
|---|---|---|---|---|
| T1 | 37,05 | 56,77 | 0,31 | Moderate |
| T2 | 40,82 | 61,32 | 0,34 | Moderate |
| T3 | 56,91 | 73,36 | 0,38 | Moderate |

Correlation coefficients between pre- and post-tests ranged from 0,892 to 0,973 ($p < 0,01$), indicating a strong and statistically significant improvement.

*Results from SD Negeri 060924*

**Table 5.** Pretest and posttest results of elementary school students 060924

| Test Pair | Pre-Test Mean | Post-Test Mean | Gain | Interpretation |
|---|---|---|---|---|
| T1 | 56,21 | 70,53 | 0,33 | Moderate |
| T2 | 67,47 | 79,79 | 0,38 | Moderate |
| T3 | 78,68 | 87,84 | 0,43 | Moderate |

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Correlation results from this school also showed strong and significant improvement (r = 0,927-0,965, p < 0,01). These results confirm that the TCK-PPDL model is moderately effective in enhancing HOTS, consistent with previous studies showing that integrated, student-centered approaches improve critical and creative thinking.[23,24]

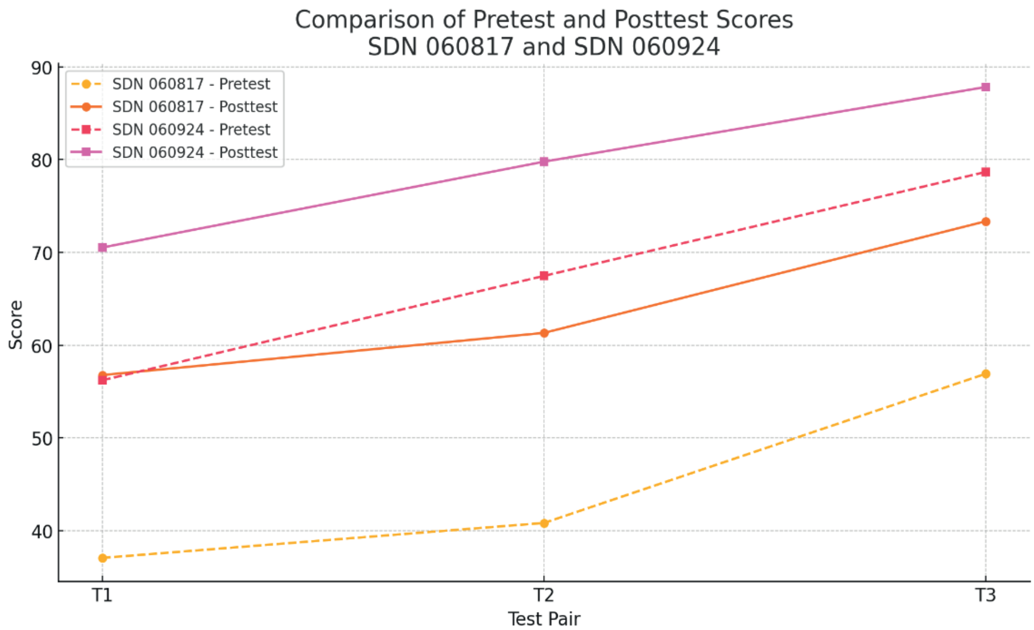


**Figure 1.** Comparison of Pretest and Posttest Scores results of elementary school students 060817 and 060924

The high levels of validity, practicality, and moderate effectiveness found in this study highlight the potential of the TCK-PPDL model as a contextually appropriate learning strategy for Indonesian elementary education. Its integration of CT and HOTS within collaborative and inquiry-based learning supports the development of 21st-century skills, as demanded by the *Merdeka Curriculum* and global educational benchmarks such as PISA.

## DISCUSSION

The TCK- PPDL model demonstrated high content validity (Aiken's V = 0,85), indicating that the design and its components are theoretically robust and practically relevant. This finding is consistent with Plomp et al.[17] who emphasized that a valid instructional design must align with pedagogical theories and be adaptable to real-world classroom contexts. Moreover, the high scores in components such as cognitive strategies and reflective learning resonate with Reigeluth et al.[19] who argue that effective instructional models must support higher-order thinking through scaffolded and reflective learning tasks.

Both teacher (87,50 %) and student (88,20 %) evaluations rated the model as "very practical," suggesting ease of implementation, relevance to curriculum goals, and meaningful student engagement. These results are supported by Dick et al.[22] who assert that the practicality of instructional materials significantly influences teacher willingness to implement innovations. Furthermore, the findings align with Weintrop et al.[25] who highlight the importance of clear, structured learning models in supporting computational thinking within science education, especially in the primary grades.

The model showed moderate effectiveness based on N-Gain scores (0,31–0,43), with strong correlations between pretest and posttest results. This outcome aligns with the study by Lu et al.[8] which found that student-centered approaches like PBL and PjBL enhance higher-order thinking when embedded in well-structured instruction. Additionally, Kim How et al.[9] emphasized that project-based tasks help students develop metacognitive and analytical skills, particularly when combined with real-life contexts—an approach used in the TCK-PPDL model.

The integration of CT within the TCK-PPDL model reflects current global trends in primary education. For instance, Angeli et al.[6] demonstrated that educational interventions integrating CT through robotics and design-based learning significantly improved children's problem-solving skills. Similarly, Wing et al.[15,26] argue that CT is not limited to programming but includes decomposition, abstraction, and algorithmic thinking—principles embedded in the six stages of the TCK-PPDL model.

The emphasis on real-world problems, collaborative exploration, and reflection is consistent with the constructivist framework outlined by Vygotsky and Larochelle et al.[23,24] These scholars assert that learning is most effective when situated in authentic contexts, allowing students to construct knowledge actively. This was reflected in the high practicality scores and student satisfaction in the current study. Kiyakbay et al.[11] also supported this, showing that project-based approaches grounded in constructivist theory foster deeper learning and cognitive transfer in middle-grade students.

The TCK-PPDL model's alignment with the Merdeka Curriculum, which promotes essential competencies, learner autonomy, and contextualized learning, makes it timely and relevant. Internationally, similar reforms have been seen in Nordic countries, where CT is introduced early in interdisciplinary learning to prepare students for a digital society.[12] The TCK-PPDL's integration of CT and HOTS into IPAS (Science-Social Studies) subjects mirrors this global movement and addresses the learning loss revealed in Indonesia's PISA 2022 results.[7]

These findings align with prior research that emphasizes the value of computational thinking in early education,[6,27] and the effectiveness of blended learning models for supporting student agency and deep learning.[11,25] Moreover, the model's emphasis on real-world application and reflection is consistent with constructivist principles and supports lifelong learning competencies

## CONCLUSIONS

The findings of this study indicate that the TCK-PPDL learning model demonstrates high content validity (Aiken's V = 0,85 on average) as confirmed by experts. Both teacher and student responses regarding the model's practicality were very high (87,50 % and 88,20 %, respectively), indicating excellent adaptability, clarity in instruction, and effective engagement.

Furthermore, the pre-test and post-test results from the two elementary schools (SD Negeri 060817 and 060924) show statistically significant improvements in students' scores and moderate N-Gain values (ranging from approximately 0,31 to 0,43). The high correlations between pre-test and post-test scores (ranging from 0,892 to 0,973 and 0,927 to 0,965, respectively) support the conclusion that the TCK-PPDL model effectively enhances students' Higher Order Thinking Skills (HOTS).

### Pedagogical Implications

The integration of computational thinking strategies with PBL, PjBL, and Discovery Learning fosters a learner-centered environment, encouraging active participation and deeper cognitive engagement. This model can serve as an effective strategy for enhancing HOTS in elementary science (IPAS) courses, aligning with the objectives of the *Merdeka Curriculum*.

### Curricular Implications

Given the model's strong alignment with current educational demands, schools can adopt the TCK-PPDL model to improve learning outcomes and better prepare students for the challenges of the digital age. Its high practicality ensures that both teachers and students can readily implement and benefit from the approach.

### Future Research

Although the moderate N-Gain results indicate room for further improvement, future studies could investigate refinements to the model—such as extended implementation cycles or integration with additional digital tools—to further enhance its effectiveness. Longitudinal research could also assess the lasting impact of TCK-PPDL on student learning and 21st-century skills development.

### Policy Implications

The success of the TCK-PPDL model provides evidence for policymakers to support innovative instructional models that integrate computational thinking and HOTS. Scaling this approach could contribute to closing performance gaps observed in national assessments like PISA and better equip future generations with critical problem-solving skills.

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The authors declare that there is no conflict of interest

## AUTHORSHIP CONTRIBUTION
*Conceptualization:* Umar Darwis, Sumarno, Sriadhi.
*Data curation:* Umar Darwis, Sumarno, Sriadhi.
*Formal analysis:* Umar Darwis, Sumarno, Sriadhi.
*Research:* Umar Darwis, Sumarno, Sriadhi.
*Methodology:* Umar Darwis, Sumarno, Sriadhi.
*Project management:* Umar Darwis, Sumarno, Sriadhi.
*Resources:* Umar Darwis, Sumarno, Sriadhi.
*Software:* Umar Darwis, Sumarno, Sriadhi.
*Supervision:* Umar Darwis, Sumarno, Sriadhi.
*Validation:* Umar Darwis, Sumarno, Sriadhi.
*Display:* Umar Darwis, Sumarno, Sriadhi.
*Drafting - original draft:* Umar Darwis, Sumarno, Sriadhi.
*Writing - proofreading and editing:* Umar Darwis, Sumarno, Sriadhi.